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ABSTRACT

Two perspectives on carrying capacity and population growth are examined. The first perspective, "Carrying Capacity and Rapid Population Growth: Definition, Cases, and Consequences" (Robert Muscat), explores the possible meanings of the idea of carrying capacity under developing country conditions, looks at historical and present-day cases of alleged overpopulation in relation to carrying capacity, discusses some of the systems and effects where such situations may be present, reviews some of the dynamic adaptions made by populations living under such pressures, and suggests some of the consequences for economic development and some of the options for public policy. The second perspective, "Carrying Capacity, Population Growth, and Sustainable Development (George Ledec, Robert J. A. Goodland, James W. Kirchner, Janet M. Drake), explores examples of human-induced reductions in long-term carrying capacity such as deforestation, desertification, loss of biological diversity, and pollution. The paper concludes that many developing countries have paid insufficient attention to policies to lower their population growth rates--relative to policies to expand substantially their carrying capacities--as a means of bringing population and natural resource availabilities into balance. (RSL)

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Rapid Population Growth and Human Carrying Capacity

Two Perspectives

Dennis J. Mahar, editor
Robert Muscat
James W. Kirchner
George Ledec
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Janet M. Drake

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FOREWORD

This paper is one in a special series of World Bank Staff Working Papers on population change and development. Prepared as background papers for the World Development Report 1984, they provide more detailed treatment and documentation of the issues dealt with in Part II of the Report. The papers cover a range of topics, including the effects of population growth and change on economic development, the determinants of fertility and mortality, the links between population growth and internal and international migration, and the management, financing, and effectiveness of family planning programs. They include several country and regional studies of fertility change and population policy.

The background papers draw on a large number of published and unpublished studies of individual researchers, on Bank policy analysis and research, and on reports of other organizations working on population and development programs and issues. The papers are the work of individuals and the views and interpretations expressed in them do not necessarily coincide with the views and interpretations of the Report itself.

I hope these detailed studies will supplement the World Development Report 1984 in furthering understanding of population and development issues among students and practitioners of development.

Nancy Birdsall
Staff Director
World Development Report 1984

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Preface

Concern about the Earth's ability to support growing populations on a sustainable basis has been widely expressed ever since the publication of Thomas Malthus' Essay on Population in 1798. Dire Malthusian predictions still appear in the literature from time to time, but their impact on public opinion has been muted in recent years by major technological advances in agriculture that have allowed increases in food production to outstrip population growth in many--though by no means in all--developing countries. Indeed, this favorable outcome has prompted many observers to discount the possibility of a global food shortage in the foreseeable future. Widespread malnutrition still exists of course--the FAO estimates that around 435 million persons were "seriously undernourished" in the developing countries (excluding China) as of the mid-1970s--but an important school of contemporary thought holds that malnutrition is more closely related to shortfalls in income than to any natural limitations on food production. The implication is that the best cure for malnutrition is broadly based economic development.

Despite the cautious optimism expressed in much of the recent literature, Robert Muscat in one paper, and James Kirchner, George Ledec, Janet Drake, and Robert Goodland in the second presented in this volume clearly indicate that the controversy initiated by Malthus nearly two centuries ago is still far from being resolved. There is no attempt here to summarize these papers in detail; the reader will find abstracts at the beginning of each paper. Suffice it to say at this point that while the subject matter of these papers is similar, and there is some overlap between them, there are some notable differences as well.

The concept of "carrying capacity," for example, is defined somewhat differently in each paper, and the sense of urgency in dealing with population pressures on natural resources varies in degree. There are also differences in scope: the paper by Muscat is mainly concerned with discussing the concept of carrying capacity, while the paper by Kirchner et al devotes greater attention to the broader relationships between population growth and environmental degradation. Both papers, however, contain useful discussions of the most pertinent issues surrounding these topics and, as such, each makes important contributions to the ongoing debate.

Demographic-nondemographic Interactions

Although the point is alluded to in both papers, it should be stressed at the outset that rapid population growth is by no means the only threat to the natural environment. By itself, it may not even be the most important one: if this were true, very little environmental degradation would be expected in the low-population-growth industralized countries. This is palpably not the case. Clearly, income-generated demands for natural resources, industrialization, urbanization, chemical-intensive farming methods, ineffective mitigatory policies, and a host of other factors have interacted with population growth to cause environmental degradation in the developed countries. Certain nondemographic factors are also present in most developing countries which, when combined with the annual population growth rates of 2-4 percent common in these countries, can make difficult environmental situations even worse. Echoing this view, the authors of a recent journal article state that "to view the problems of environmental deterioration in developing countries as a consequence of growing populations and rising subsistence requirements is to oversimplify and, in some ways, to mistake the current situation." [1]

There are at least three factors or processes that, along with population growth, can contribute in important ways to environmental deterioration in developing countries: inequality in access to natural resources, particularly agricultural land; commercialization of production; and the breakdown of traditional resource management systems under external pressures. The first can amount, in essence, to a premature closing of the land frontier. Since growing populations are prevented from expanding onto the better soils reserved for large landholders, they are forced to over-intensify cultivation of their own holdings to meet subsistence needs or (if the option is available) to move to unoccupied, ecologically sensitive areas. (This process is akin to the "low-potential region phenomenon" discussed in both the Muscat and the Kirchner *et al* papers.) It is indeed unfortunate that governments in many developing countries invest in the agricultural development of sparsely populated marginal lands instead of pursuing policies--such as land reforms--that would increase the productivity and absorptive capacities of already-settled, high-potential regions.

The commercialization of production is a process whereby environmental degradation can occur even without population growth. This is most clearly demonstrated by the development of export-oriented logging operations in the tropical forests of Asia, Africa and Latin America. By and large, such operations are spurred by income-generated demand in the developed countries, not population growth in the developing countries themselves. It can be argued that the foreign exchange earnings made possible by these exports facilitate imports of food and other goods in short supply in the exporting country, but these economic gains are often short-lived. As pointed out by Kirchner _et al_, the indiscriminate cutting of tropical forests initiates a chain of events--for example, soil erosion and laterization--that may preclude the use of the deforested area, for agricultural or other productive purposes, by future generations.

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[1] R. Repetto and T. Holmes, "The Role of Population in Resource Depletion in Developing Countries," *Population and Development Review* 9, 4 (1983), 609.

Finally, social changes precipitated by external pressures can also bring ecological threats. In Kenya and Uganda pastoral groups, whose political power was destroyed under colonial rule, have seen their closed system of communal management converted into open access to their land. With added population growth, overgrazing and severe environmental damage have followed. In Brazil and Indonesia the concession of generous incentives to large companies to engage in ranching and logging operations in areas of tropical forest have undermined the social organization of indigenous communities. This has also made these areas more ecologically vulnerable to increasing population pressures.

Policy Implications

Policies to slow population growth will not, by themselves, be an immediate panacea for problems of low productivity and resource depletion in the developing countries. Indeed, some countries--for example, the land-abundant countries of central Africa--could even benefit from higher population densities in rural areas since this would permit economies of scale in the provision of infrastructure and public services. On the other hand, countries experiencing rapid population growth will find it more difficult to finance the investments in human and physical capital necessary for sustained, and ecologically sound, economic development. The management of natural resources use will also be complicated by rapid population growth, particularly if increasing pressures on land contribute to migration to remote areas where administrative personnel are thinly spread. The ideal approach, therefore, would be to combine population policies with others--for example, land-use zoning, land reforms, agronomic research--directed to ensure that a country's resource base is developed in an equitable and sustainable manner.

Dennis J. Mahar

Préface

Depuis la parution de l'Essai sur le principe de population de Thomas Malthus en 1798, nombreux sont ceux qui se demandent si la Terre pourra faire vivre indéfiniment un nombre croissant d'habitants. De sinistres prédictions de type malthusien sont occasionnellement imprimées, mais leur retentissement dans l'opinion publique est atténué depuis quelques années par l'annonce de progrès majeurs en agriculture, grâce auxquels la production a augmenté beaucoup plus rapidement que la population dans de nombreux pays en développement - pas dans tous, tant s'en faut. De fait, la tournure favorable des événements a incité maints observateurs à écarter la possibilité d'une pénurie alimentaire globale dans un avenir prévisible. Certes, la malnutrition sévit encore dans de nombreuses régions - la FAO estime qu'environ 435 millions de personnes étaient "gravement sous-alimentées" dans les pays en développement (Chine non comprise) au milieu des années 70 - mais une importante école de pensée contemporaine soutient que la malnutrition résulte davantage de l'insuffisance du revenu que de limites naturelles à la production alimentaire. En d'autres termes, le meilleur remède contre la malnutrition résiderait dans un développement économique largement réparti.

En dépit de l'optimisme prudent dont une grande partie des ouvrages récents se font l'écho, Robert Muscat, dans l'une des études présentées dans ce volume, et James Kirchner, George Ledec, Janet Drake et Robert Goodland dans la deuxième, indiquent clairement que la controverse ouverte par Malthus voici près de deux siècles est encore loin d'être résolue. Sans chercher à résumer ici en détail ces deux documents, dont le lecteur trouvera un condensé avant le corps du texte, on se bornera à signaler que s'ils traitent d'un sujet analogue et présentent des chevauchements sur certains points, il s'y trouve cependant des différences notables.

La définition de la "capacité de charge", par exemple, n'est pas la même dans les deux études, et le degré d'urgence du problème de la pression démographique sur les ressources naturelles varie. Le thème aussi est légèrement différent : l'ouvrage de Muscat analyse essentiellement la notion de capacité de charge, tandis que celui de Kirchner *et al*. s'intéresse plutôt aux relations entre l'accroissement de la population et la dégradation de l'environnement. Toutefois, les deux textes contiennent un examen utile des questions les plus pertinentes dans ces domaines et, à ce titre, ils apportent chacun leur pierre au débat.

Interaction entre facteurs démographiques et non démographiques

Il convient de souligner d'emblée un élément auquel les deux études font allusion, à savoir que la poussée démographique n'est pas la seule menace qui pèse sur l'environnement naturel. Prise isolément, ce n'est peut-être pas la plus grave : si cela était vrai, l'environnement ne subirait que très peu de dégradations dans les pays industrialisés où la population augmente lentement. Or, il n'en est manifestement rien. Il est évident que la demande de ressources naturelles engendrée par le revenu, l'industrialisation, l'urbanisation, les méthodes agricoles à forte consommation de produits chimiques, les palliatifs qui n'atteignent pas leur but et une multitude d'autres facteurs, se sont combinés avec l'accroissement de la population pour dégrader l'environnement dans les pays développés. Certains facteurs non démographiques sont en évidence dans la plupart des pays en développement aussi. Lorsqu'ils se conjuguent, comme c'est trop souvent le cas, à des taux de croissance démographique de 2 à 4 %, la situation écologique déjà précaire peut s'aggraver encore. Ainsi pouvait on lire dans un article : "Ceux qui voient dans les problèmes de dégradation de l'environnement des pays en développement la conséquence de l'accroissement de la population et de l'augmentation des besoins de subsistance, ont une vision simpliste, pour ne pas dire erronée, de la situation actuelle." 1/

Au moins trois facteurs ou processus contribuent largement, en même temps que l'accroissement de la population, à la dégradation de l'environnement dans les pays en développement : l'inégalité d'accès aux ressources naturelles, en particulier aux terres agricoles; la commercialisation de la production; et l'effondrement des systèmes traditionnels de gestion des ressources, sous l'effet des pressions externes. Le premier facteur peut déboucher sur l'épuisement prématuré des terres agricoles. En effet, des populations de plus en plus nombreuses se voyant refuser l'accès aux meilleures terres, réservées aux gros exploitants, sont contraintes d'intensifier à l'excès la culture des parcelles qu'elles détiennent pour satisfaire leurs besoins de subsistance ou, si cette option existe, de mettre en culture des zones écologiquement fragiles. (On se référera au "phénomène des régions à faible potentiel"

1/ R. Repetto et T. Holmes, "The Role of Population in Resource Depletion in Developing Countries", Population and Development Review 9, 4 (1983), 609.

dont parlent aussi bien Muscat que Kirchner _et al._) Il est dommage que tant de pays en développement investissent dans la mise en valeur de terres marginales peu peuplées au lieu de prendre des mesures, telles qu'une réforme foncière, propres à accroître la productivité et la capacité d'absorption de régions déjà peuplées et à fort potentiel.

Le processus de commercialisation de la production fait que l'environnement peut se dégrader même si la population n'augmente pas. La meilleure illustration en est le développement de l'exploitation forestière pour l'exportation dans les forêts d'Asie, d'Afrique et d'Amérique latine. Dans l'ensemble, ces opérations résultent directement de la demande engendrée par le revenu dans les pays développés et non pas de l'accroissement de la population dans les pays en développement eux-mêmes. Certes, ces exportations procurent des devises qui facilitent l'importation de produits alimentaires et autres biens qui manquent dans le pays exportateur, mais ces bénéfices économiques sont souvent éphémères. Et comme le soulignent Kirchner _et al._, l'exploitation aveugle des forêts tropicales déclenche une série d'événements, tels que l'érosion des sols et la latéritisation, qui peuvent interdire l'usage de la zone déboisée pour l'agriculture ou pour d'autres fins par les générations futures.

Enfin, l'accélération des changements sociaux sous l'effet des pressions extérieures peut être préjudiciable à l'écologie. Au Kenya et en Ouganda, les groupes de pasteurs, dont le pouvoir politique a été annihilé sous le régime colonial et qui avaient un système fermé de gestion communautaire, ont vu ouvrir l'accès à leurs terres. L'accroissement rapide de la population s'est soldé par le surpâturage et une dégradation sérieuse de l'environnement. Au Brésil et en Indonésie, les avantages généreux accordés aux grandes compagnies pour qu'elles se lancent dans l'élevage en ranches et l'exploitation forestière dans les zones de forêt tropicale, ont sapé l'organisation sociale des communautés autochtones, ce qui a rendu l'écologie de ces régions moins à même de résister à l'augmentation de la pression démographique.

Incidences sur l'action des pouvoirs publics

Les mesures visant à ralentir l'accroissement de la population ne remédieront pas miraculeusement aux problèmes que sont la faiblesse de la productivité et l'épuisement des ressources dans les pays en développement. En fait, certains pays, par exemple ceux d'Afrique centrale, qui ont abondance de terres, gagneraient à avoir de plus fortes densités de population dans les zones rurales, pour réaliser des économies d'échelle dans la mise en place de l'infrastructure et des services publics. Cependant, les pays où la population augmente rapidement auront plus de mal à financer l'investissemnt dans le capital humain et matériel indispensable à un développement économique soutenu et sans danger pour l'environnement. Un accroissement rapide de la population compliquera également la gestion des ressources naturelles, à plus forte raison si l'alourdissement de la pression sur la terre pousse la population à aller s'installer dans des zones éloignées, où les services administratifs sont clairsemés. L'approche idéale, par conséquent, consisterait à agir simultanément sur plusieurs fronts, par des programmes de population, des plans d'utilisation des sols, des réformes foncières, la recherche agricole, etc., de façon que la base de ressources nationale soit mise en valeur de manière équitable, sans hypothéquer l'avenir.

Dennis J. Mahar

Prefacio

Desde la publicación del Ensayo sobre el principio de la población de Thomas Malthus en 1798, se ha expresado amplia preocupación sobre la capacidad de la tierra para mantener crecientes poblaciones sobre una base sostenible. Aún aparecen de vez en cuando en la literatura funestas predicciones maltusianas, pero sus efectos en la opinión pública han disminuido en los últimos años debido a importantes avances tecnológicos en la agricultura que han permitido que los aumentos en la producción de alimentos excedan el crecimiento de la población en muchos países en desarrollo, aunque de ninguna manera en todos ellos. Este resultado favorable ha llevado incluso a muchos observadores a descontar la posibilidad de una escasez mundial de alimentos en el futuro previsible. Naturalmente, aún existe la malnutrición generalizada --la FAO estima que alrededor de 435 millones de personas estaban "gravemente desnutridas" en los países en desarrollo (con exclusión de China) a mediados del decenio de 1970-- pero una importante escuela de pensamiento contemporáneo sostiene que la malnutrición se relaciona más estrechamente con la insuficiencia de ingresos que con cualquier limitación natural de la producción de alimentos. El corolario es que la mejor cura para la malnutrición es el desarrollo económico de base amplia.

No obstante el cauteloso optimismo expresado en gran parte de la literatura reciente, Robert Muscat en un documento, y James Kirchner, George Ledec, Janet Drake y Robert Goodland en el segundo presentado en este volumen demuestran claramente que la controversia iniciada por

Malthus hace casi dos siglos aún dista mucho de resolverse. No se intenta aquí resumir esos documentos en detalle; el lector encontrará extractos al comienzo de cada uno. Baste decir aquí que, si bien el tema en los dos es similar y hay cierta superposición entre ellos, también hay algunas notables diferencias.

Por ejemplo, el concepto de "capacidad de sustento" se define de manera algo diferente en cada documento, y la impresión de urgencia para abordar las presiones demográficas sobre los recursos naturales varía de grado. También hay diferencias de alcance: el documento de Muscat se refiere principalmente al análisis del concepto de la capacidad de sustento, en tanto que el de Kirchner y otros dedica mayor atención a las relaciones más amplias entre el crecimiento de la población y el deterioro ambiental. Pero ambos documentos contienen análisis útiles de los problemas más pertinentes en torno a estos temas, y de este modo cada uno hace importantes contribuciones al debate en curso.

Interacciones demográficas y no demográficas

Aunque en ambos documentos se alude al punto, debe hacerse hincapié desde un principio en que el rápido crecimiento de la población no plantea de ninguna manera la única amenaza al ambiente. Por sí solo incluso puede no ser el más importante: si así fuera, se prevería muy poco deterioro ambiental en los países industrializados con bajo crecimiento de la población. Este no es evidentemente el caso. Es claro que las demandas generadas por los ingresos respecto a recursos naturales, la industrialización, la urbanización, los métodos agrícolas con utilización intensiva de productos químicos, las políticas ineficaces de alivio y un sinnúmero de otros factores han influido recíprocamente con el crecimiento de la población para causar deterioro ambiental en los países desarrollados. También están presentes en la mayoría de los países en desarrollo algunos factores no demográficos que, al combinarse con las tasas anuales de crecimiento de la población de 2% a 4% que son corrientes en estos países, pueden hacer aún peores las condiciones ambientales ya difíciles. Haciéndose eco de esta opinión, los autores de un reciente artículo señalan que "considerar los problemas del deterioro ambiental en los países en desarrollo como consecuencia del aumento de la población y de crecientes necesidades para la subsistencia es simplificar en exceso y, en algunos casos, interpretar mal la actual situación" 1/.

Hay por lo menos tres factores o procesos que, junto con el crecimiento de la población, pueden contribuir de maneras importantes al deterioro ambiental en los países en desarrollo: la desigualdad del acceso a los recursos naturales, en especial las tierras agrícolas; la comercialización de la producción, y el colapso de los sistemas tradicionales de administración de recursos bajo presiones externas. El primero puede equivaler en esencia a un cierre prematuro de la frontera de tierras. Debido a que se impide a las crecientes poblaciones extenderse hacia mejores suelos, reservados para los grandes terratenientes, se ven obligadas a intensificar en exceso el cultivo de sus propios predios para satisfacer las necesidades de subsistencia o (si se dispone de la opción) trasladarse a zonas desocupadas y ecológicamente delicadas. (Este proceso

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1/ R. Repetto y T. Holmes, "The Role of Population in Resource Depletion in Developing Countries," Population and Development Review 9, 4 (1983), 609.

es igual al "fenómeno de la región de bajo potencial" que se analiza en los documentos de Muscat y de Kirchner y otros.) Es en verdad lamentable que los gobiernos de muchos países en desarrollo inviertan en el mejoramiento agrícola de zonas marginales escasamente pobladas en lugar de aplicar políticas --como la de reforma agraria-- que aumenten las capacidades productivas y de absorción de regiones ya colonizadas y de elevado potencial.

La comercialización de la producción es un proceso mediante el cual el deterioro ambiental puede ocurrir incluso sin el crecimiento de la población. Esto queda claramente demostrado por el auge de las operaciones de extracción de madera orientadas a la exportación en las selvas tropicales de Asia, Africa y América Latina. En general, estas operaciones son alentadas por la demanda generada por los ingresos en los países desarrollados, y no por el crecimiento de la población en los propios países en desarrollo. Puede argumentarse que los ingresos de divisas que estas exportaciones hacen posibles facilitan las importaciones de alimentos y otros bienes que escasean en el país exportador, pero a menudo estos beneficios económicos son de breve duración. Como señalan Kirchner y otros, la tala indiscriminada en las selvas tropicales inicia una cadena de acontecimientos --por ejemplo, la erosión del suelo y la laterización-- que pueden impedir que futuras generaciones utilicen la zona desforestada para la agricultura u otros fines productivos.

Finalmente, los cambios sociales provocados por las presiones externas también pueden acarrear amenazas ecológicas. En Kenya y Uganda, los grupos dedicados al pastoreo, cuyo poder político desapareció bajo el dominio colonial, han visto su régimen cerrado de administración comunal convertido en sistema de libre acceso a sus tierras. Con el mayor crecimiento de la población sobrevino el exceso de pastoreo y el grave daño ambiental. En el Brasil e Indonesia, la concesión de generosos incentivos a las grandes empresas para que se dedicaran a operaciones de ganadería y explotación forestal en zonas de selvas tropicales ha socavado la organización social de las comunidades autóctonas. Esto ha hecho también que estas zonas sean ecológicamente más vulnerables a las crecientes presiones demográficas.

Repercusiones en materia de políticas

Las políticas para disminuir el crecimiento de la población no serán por sí solas la panacea inmediata para los problemas de la baja productividad y agotamiento de los recursos en los países en desarrollo. En efecto, algunos países, por ejemplo los de Africa Central que tienen abundancia de tierras, podrían incluso beneficiarse de densidades más altas de población en las zonas rurales, puesto que ello permitiría economías de escala en el suministro de infraestructura y servicios públicos. Por otra parte, a los países que experimentan rápido crecimiento de la población les resultará más difícil financiar las inversiones en capital humano y físico que son necesarias para el desarrollo económico sostenido y ecológicamente seguro. La administración de la utilización de recursos naturales se verá también complicada por el rápido crecimiento demográfico, en especial si las crecientes presiones sobre la tierra contribuyen a la migración hacia zonas muy alejadas donde hay poco personal administrativo. Por consiguiente, el enfoque ideal sería combinar políticas de población con otras, por ejemplo, la zonificación de tierras, la reforma agraria, la investigación agronómica, todas ellas orientadas a asegurar que la base de recursos de un país se desarrolle de manera equitativa y sostenible.

Denis J. Mahar

CARRYING CAPACITY AND RAPID POPULATION GROWTH: DEFINITION, CASES, AND CONSEQUENCES

Robert Muscat

Abstract

The most dire consequences of rapid population growth are thought by some to emerge in places where the size of the human population exceeds the carrying capacity of the land. This paper explores the possible meanings of the idea of carrying capacity under developing country conditions, looks at historical and present-day cases of alleged overpopulation in relation to carrying capacity, examines some of the systems and effects where such situations may be present, reviews some of the dynamic adaptions made by populations living under such pressures, and suggests some of the consequences for economic development and some of the options for public policy.

Analogies between present-day populations and the biological limitation and adjustment mechanisms of animal or remote hunter-gatherer human groups to their environments are found to be misleading. A particular environ-ment (or geographic or national area) limits the human population that can be carried (at a given level of income per capita) only under several restrictive conditions: the economy is closed, offering no possibilities for comparative advantages that might reduce dependence on the physical environment; technology remains unchanged; and there is no net capital accumulation in any form that would increase productivity. Where these conditions are not operating, this century has seen several economies with limited agricultural potential (and very poor natural resource bases) achieve high per capita income and increasingly dense human settlement.

Nevertheless, there are areas where the above conditions are in fact approximated--for reasons of poverty, policy, weakness of institutional structure, and paucity of scientific research and better technologies--and where rapid population growth is pressing against the agricultural resource endowment. This paper illustrates four types of contemporary carrying capacity problem situations: the "backward" region problem of countries experiencing no inherent economic capacity or income limitations in the rest of their habitable areas; countries where growing populations in well-endowed regions are migrating to less well-endowed, previously thinly populated areas, and settling the latter areas before technologies appropriate to their fragile ecologies have been developed; countries where traditional seasonal or cyclical adjustments to land pressure have been hindered by modern borders and barriers to regional migration; and countries--largely agricultural--where low productivity and ecological fragility (as confined to the "backward" region elsewhere) are general throughout the country and recent population growth has run long enough to bring about secular deterioration in the population/capacity relationship. Adjustments in these cases are described and some policy considerations discussed.

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Introduction

The most dire consequences of rapid population growth are thought by some to emerge in places where the size of the human population exceeds the carrying capacity of the land. The notion of carrying capacity is not rigorously defined or examined in the literature on the consequences of "overpopulation". Its usual intuitive sense refers to the food production being drawn from the areas in question, but also extends to other basic land yields--water and fuelwood--essential for human settlement in the circumstances common to low-income populations. In what appears as straightforward common sense, the carrying capacity of a region usually is defined as a maximum value of the ratio of population to food production. Where the rate of increase in the numerator is projected to exceed the rate of growth in the denominator, the ratio yields a diminishing per capita food outcome. Below some threshold per capita level, carrying capacity has been exceeded because average food availability has declined to unacceptable levels, and the general risk of famine has increased to dangerous proportions.

This paper explores the possible meanings of the idea of carrying capacity under the specific conditions found in developing countries, looks at historical and present-day cases of alleged overpopulation in relation to carrying capacity, examines some of the symptoms and effects where such situations may be present, reviews some of the dynamic adaptations made by populations living under such pressures, and suggests some of the consequences for economic development and some of the options for public policy. We will try to illustrate the conditions and consequences involved, but will not attempt original research.

This paper will not consider the extensive debate in recent years on carrying capacity of the earth as a whole. Barring the uncertain possibilities that economic activity may have cumulative bad effects on the atmosphere, the author believes the optimists currently have the stronger case, and that the carrying capacity of the planet in terms of food (and other raw materials) appears to be well in excess of any likely human population magnitudes for the next century. Whether or not the long-run global concerns turn out to be real, however, countries that face carrying capacity limitations over the next ten to twenty years will have to deal with them even if the rest of the world is poised for sustainable growth indefinitely without significant environmental or resource constraints.

We also put aside sheer crowding, an aspect of carrying capacity that has had some vogue despite the obvious capacity of humans to adjust to high densities, even to prefer high density if one can judge from "city lights" attraction over the past century almost everywhere. The ability to adapt to high density appears to have a very wide boundary. In addition some of the most densely populated places are among the world's richest jurisdictions, and some are at the same time highly orderly, suffering from lower per capita rates of violence and other social ills than other areas with lower densities. (Furthermore the usual definition of density is not adequate for urban areas where spatial extension per capita is multiplied by high-rise buildings for work and residence.) In these numerous cases, neither the land nor the resident populations show positive correlation between density and deterioration. There is some evidence, however, that the perception of crowding may have significant effects on local fertility behavior, in addition to migratory and other economic behavior. Looking at carrying capacity from the simple spatial aspect suggested in these situations has some possible policy implications to which we will return below.

Carrying Capacity: Definition From Analogy

In the demography of animals it is known that local or regional populations have elaborate adaptation processes that respond to changes in the availability of food. As the carrying capacity determined by natural food supply fluctuates, different species, in different ways, adjust their numbers in the same direction. Seasonal migration, cycles in mortality and fertility, or a drastic reduction in numbers during extended periods of drought, are among the demographic responses widely observed.

These responses reflect the very direct dependence of animal populations on the volume of food and water they are able to cull from their areas of residence. Species anywhere in the food chain may be affected by changes in the supply of vegetation or animate species lower in the chain, or a change in the underlying supply of nutrients on which they are dependent indirectly through intermediary species. If the option of migration is not open, a species must adjust locally by hibernating or by seasonally or cyclically fluctuating in population size.

At the point where a local animal population is forced to adopt behavior reducing its numbers in the face of reduced food supply, its population has exceeded the short-run carrying capacity, specific to that species, of its environment. The modern-day destruction of natural habitats offers many examples of the decline and extinction of animal populations as the carrying capacity has shrunk below some minimum threshold for the species' viability. The seasonal and cyclical fluctuations in the wild, however, are more ambiguous as examples of stress on a local population. Such fluctuations normally are part of a recurrent biological adaptation to a regularly fluctuating environment, with each population as a whole successfully coping with the conditions of its ecological niche. During cycles in mortality, the strongest individuals survive into the next upturn in the environment's carrying capacity. Since the mortality increases are inherent in a population's coping behavior, they are not an indication that the population has exceeded the long-run carrying capacity of its environment.

Anthropologists studying human pre-history have concluded that early human groups went through periods of varying population growth rates in response to changes in the food supply in their particular niches and improvements in their food acquisition techniques. In long periods of unchanging supply and technology, there is evidence that these populations employed artificial controls such as infanticide to sustain constant population levels (Thomas 1971).

The Bushmen of the Kalihari desert appear to be a present-day human population living under conditions similar to early man, and in analogous relationship to their environment as other species in terms of the close dependency of their numbers on the carrying capacity of the area of residence of a hunter-gatherer system. One Bushmen community closely examined had the following characteristics.

The members lived in "comfortable" equilibrium with a severe local environment. They hunted a variety of game, which were not abundant, and gathered a variety of plants. They were unable to store any food and kept only a few hunting dogs and domestic animals. Life was lived in frequent treks for food and water and in frequent circulations among eight waterholes as local food supplies were temporarily depleted. Caloric acquisition was calculated to exceed their energy requirements, the surplus being given to the dogs. About two-thirds of the 248-person community worked and only about a third of the working population's time was devoted to food collection. The study showed that "a relatively small subsistence effect was more than enough to provide an adequate diet for the !kung Bushmen. They do not live in privation, and they do not suffer from population pressure." Birth control was "rigidly practiced." Thus the community has achieved an equilibrium between its numbers, its caloric acquisition, and its leisure preferences. While the population is not up against the carrying capacity of the environment in a technical sense (there is scope for trading leisure for more food acquisition or water trekking), carrying capacity does place a major constraint on population size and the income they enjoy, as directed by their deliberate attention to their numbers and the dependency ratio. Living in relative isolation and without conflict with other Bushmen communities, there is no defense or territorial rivalry motive for promoting population increase that would upset their equilibrium.

The essential differences between these rare circumstances and the more common situation of agricultural populations are readily apparent: (1) The Bushmen were not tied to a larger system of government under which deliberate effects were being made to raise income levels by pushing back production constraints; (2) technological development was at a low level and little changed over time; (3) their economy was closed, that is, there was no trade that offered the possibility of introducing new tools, stimulating new demands, or offering the option of searching for comparative advances that might loosen their complete dependence on culling from the local environment; (4) there was no net capital accumulation in any form that would increase their ability to exploit the land and; (5) there was no migration out of the area.

In sum, with no changes in technology, capital, or location, the community could vary only its numbers and its leisure/work time allocation. Under these highly limiting conditions, the carrying capacity of the land (in combination with the work/leisure preference function) completely determined the community's size.

In the long run it is evident that advancing technology and accumulation of capital, and the declining importance of agriculture in the structure of production and distribution of the labor force, greatly reduce the dependence of human populations on the inherent fertility and raw material endowment of their particular environments. For some high-income populations trading a significant portion of their domestic product--for example, Japan, Switzerland, Israel, Singapore--the inherent qualities of their own area have become almost irrelevant to their economic activity (location and tourism aside), and constitute no barrier to dense settlement at high income levels.

Finally, in the way of a footnote, mention should be made of countries that have suffered sharp declines in food availability due to economic policies that discourage the agriculture sector from producing a surplus for sale to the urban populations and that bring on a balance of payments crisis constraining the country's food import capacity. In a sense the carrying capacity of the entire economy has been reduced through a drop in its efficiency. But such situations are not examples of the kind of numerical, low-income demand pressure on the physical limits of the land that is the problem addressed by the carrying capacity limits literature.

The "Land Resources for Populations of the Future" Project

As an introduction to the discussion of carrying capacity pressure under modern conditions, it is useful to consider what is probably the most recent statement of the thesis that numerous developing countries face the prospect of hitting carrying capacity ceilings to further income growth (and sheer eating) within a relatively short time period. In an article in Earthwatch magazine, Paul Harrison summarizes the results of a elaborate study being performed by FAO and the International Institute for Applied Systems Analysis (IIASA) under UNDP funding (Harrison 1983). According to Harrison, a participant in the study, the Land Resources for Populations of the Future project has reached "alarming" conclusions after an analysis of data on 117 countries designed to project their land's population carrying capacity as measured by their "population/resources equation."

The methodology for the study was developed by the Land and Water Division of FAO and IIASA. Data on soil and land characteristics were combined with climate data to divide the developing world into a mosaic of tens of thousands of units. For each cell, a computer program calculated the potential yields of major food crops, selected the optimum crop, and derived the caloric yield potential. Summing the yield units by country and dividing by the minimum recommended caloric intake for each country, the study derives a maximum population that can be fed at the minimum intake level for the years 1975, 2000, and 2015. The UN "medium variant" population projections were used to compare with the "supportable" populations in the two projection years. Finally, three variant potential caloric outputs were calculated based on three levels of technology. The low level consists of what one would find in areas of traditional cultivation: no fertilizer or chemicals, traditional varieties, no soil conservation methods. The intermediate level assumes the most productive crop mix is applied on half the land along with the fertilizer, improved varieties and some conservation. The high level corresponds to North American technology with an ideal crop mix and technology on all lands.

Harrison writes that the study presents "an unanswerable challenge to the fashionable school of thought which holds that there are no limits to food production except those deriving from social and economic structures, and there is no such thing as overpopulation." While the study shows that on a global basis the 117 countries could produce a total food output, even at the low level of technology, sufficient to support one and a half times their projected year 2000 population, disaggregation by country reveals different and serious outcomes. Sixty-five countries with a population of nearly 1.1 billion (29 percent of the total) would be unable to feed their inhabitants at the minimum standard, with the number in excess of carrying capacity estimated at 440 million. Of these countries, 30 (out of 51) would be African, 15 (out of 16) southwest Asian, 14 (out of 21) Central American and the Caribbean, and 6 (out of 16) other Asian.

In contrast with the doomsday tone of the conclusion drawn, the exposition goes on to note that 29 of the countries would drop from the list if they achieved an intermediate level of inputs, and another 17 if they could reach high levels. A core of 19, with a population of about 100 million, would remain unable to feed themselves, even with the most advanced methods. Twelve of these latter countries would be in southwest Asia. Unfortunately, the article does not give a country breakdown. It is unavoidable, however, that several of the southwest Asian countries must be oil exporting countries, including some in the World Bank category of capital-surplus oil exporters.

For this group, the inability to produce sufficient food domestically can hardly be labelled an alarming condition. *

Finally, the argument gives reasons why the numerical conclusions underestimate the real gravity of the "coming mismatch between population and land resources." Food production will actually be less because some land will be devoted to non-food crops, some will be lost to non-agricultural uses, food distribution will be unequal among social groups, and effective demand (for meat, for example) will run ahead of the caloric per capita minimum. At the same time, it is admitted that the study is based on a one-sector, closed-economy model. No attempt was made to assess if countries could develop economic structures that included significant international trade, an outcome in which "inability to feed their population from their own land is less of a problem."

One could quarrel with some of the assumptions and steps in the analysis. If land is diverted to non-food crops that earn higher returns, the potential food supply outcome (and income position) will be better, not worse, than if the land devoted to producing own-consumption of food had been maximized. If effective demand is rising to levels where characteristic dietary diversification preferences appear, real income based on some productive or service activities must be growing, activities that may reflect comparative advantages and entail an enhanced ability of the economy to import food, among other things. In general, the assumption of closed economies

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* Editor's note: The full technical report of the project (G. M. Higgins et. al, Potential Population Supporting Capacities of Lands in the Developing World, Rome: FAO, 1982) indicates that the 12 southwest Asian countries include: Lebanon, Israel, Yemen Arab Rep., Afghanistan, Jordan, Yemen PDR, Saudi Arabia, United Arab Emirates, Kuwait, Oman, Qatar, and Bahrain. The 7 remaining countries include: Mauritius, Rwanda, Cape Verde and Western Sahara (Africa); Barbados and Netherlands Antilles (Central America and the Caribbean); and Singapore (southeast Asia).

inevitably results in the inefficiencies of autarchy. Whether or not the possible outcomes should be described as grave depends on one's assessment regarding the speed with which research will yield improved technologies, and with which the countries will develop the institutional base for modernizing their agricultural sectors; the extent to which government price and other market intervention policies will assist or hamper the development of incentive structures in which farmers will make their production decisions; the flow of external aid; the growth of international trade, including preferential systems; and so forth.

The key assumptions in the serious carrying capacity cases are as follows:

1. Either all arable land has already been put into production or any remaining land is of lower inherent productivity so that at the given technology and level of investment in land improvement (if any), the marginal land yields lower returns than the average.

2. International or interregional trade plays a minor role. In the time frame of the projections, diversification with changing mixes of domestic and imported food as relative prices change over time, is assumed to offer only minor scope for adjustment to the domestic food production/consumption relationship. The scenario is drawn out at great length and detail with respect to the food supply (and non-food agriculture) not entering trade, but the trade sector is unexplored and assumed by implication to be trivial.

3. The rate of change in agricultural productivity is assumed to be slow. For much of the African region, in fact, the above study appears to contain implicit assumptions about research results still uncertain for many of Africa's under-researched local environments. In this respect it may be optimistic for some countries.

4. Related to the assumption of slow change in agricultural technology is the assumption that capital deepening to raise the effectiveness of existing technologies is also likely to be slow and offer only a minor additional degree of freedom.

Finally, there is the question of the upshot. If the expected conditions in fact occur, what will be the effects? What are the symptoms or indicators? What processes will be set in motion when capacity begins to be "exceeded"? What determines the time frame of these processes? We will consider these questions below, after proposing a definition and identifying some actual cases under modern conditions where the concept of pressure against carrying capacity has meaning.

In the animal and bushmen situations, the carrying capacity of the bounded environment for one species can be defined as the maximum number of members of that species that can maintain a minimum diet. Although some of the terms of this formulation are ambiguous, the general sense is clearly what the FAO/IIASA study also has in mind. The maximum number should be thought of as representing a range since the average caloric requirement concept is still being debated by the nutritionists, and for individuals and groups will vary depending on the extent of infectious diseases, the amount of social activity normally exercised beyond the caloric expenditures for sheer food acquisition, the demographic composition of the population, and so forth. If the population grows larger after the threshold range has been reached, and the food supply remains unchanged, average caloric intake falls below the recommended minimum. In practice, in situations of extreme food stress the distribution of the shortfall will be uneven, and social and economic factors will determine which families and which members suffer disproportionate declines in food intake. Mortality levels will rise selectively among these cohorts.

Other adjustments will include a decrease in or elimination of discretionary activity so that the minimum requirement level for healthy survival over the food stress period is consciously lowered below the customary minimum requirement level.

These fine points aside, the Malthusian notion of a population pressing against the food supply has historical cases behind it. The economic historian J.D. Gould has described cases of populations exceeding carrying capacity and the attendant adjustment processes (Gould 1982). He cites the "dire consequences of a combination of increasing population density and technical stagnation in a predominantly agricultural society: Ireland in the first half of the nineteenth century and Russia in the second." He discusses the long data series for England (difficult to interpret, to be sure) that appears to show five and a half centuries of secular fluctuations in real income related primarily to changes in the ratio of the population to the land, with purchasing power and population inversely correlated. There were adaptive responses in English agricultural techniques and organization but they were slow to affect productivity. These changes in technology apparently were not adequate to sustain domestic food supply growth at the same rate as population growth in the late Tudor period, a significant cause of the sharp fall in industrial real wages believed to have occurred at that time.

Under pre-scientific agricultural conditions, even without deliberate government interventions, adaptions of the following kinds took place where increasing population made it difficult to sustain the traditional level of per capita food output:

1. Where land was available, families avoided subdivision and decreasing income by sending members to settle on unoccupied land. This process was described for southeast Asia by H. Myint under the term "vent for surplus."

The opening of the Suez Canal brought export demand to the rice deltas for the first time. Using a constant technology in areas where soil nutrients were annually restored by flooding, population growth (and the application of previously available leisure time to land preparation and cultivation) enabled those regions to expand output and at least maintain income levels over the ensuing century as the number of inhabitants gradually expanded to fill up the arable space, with constant returns to scale.

2. Where this "vent" does not exist, the population may raise the effective cultivated area by increasing the ratio of years of cultivation to years of fallow, as was done in England for example. The extent of this change in technology depends on the speed of natural fertility regeneration and the adoption of manuring practice.

3. Where rainfall is adequate and temperature high enough for enough months, double-cropping of some species has been introduced, an adaptation generally limited to tropical regions.

4. Local small-scale irrigation from rivers or catchment basins has been introduced by farmers themselves through local organization.

Such measures push back the income decline implied by rising population "pressure", but as Gould concludes, "agricultural output may be able to respond - but as the limits (and there surely must be limits) of pre-scientific productivity are approached the response may be less than complete; and in any event it may come too slowly if population densities increase even moderately quickly (Gould 1982, p. 86)." The time frame in which capacity pressure emerges thus depends on the relationships between population growth rates, arable area, and technological change.

Carrying Capacity Under Modern Conditions

We may restate the conditions under which carrying capacity pressure is found today, noting the contrasts with more limiting circumstances of the anthropological and historical cases. First, the isolation of agricultural regions has been greatly reduced. Physical access for movement of bulk commodities has been improved through inland rail and road networks and extension of port capacities. Second, elaborate systems have been created for international financial transfers to supplement the import capability of low-income countries. These systems provide historically unprecedented levels of per capita resource transfers, especially for the least developed countries, enhancing their ability to invest in raising the productivity of their land.

Third, unprecedented systems of scientific research on the production problems of lagging agricultural regions have been created in recent years, including both the international CGIAR institutions any many national facilities. Centers such as the International Institute of Tropical Agriculture (IITA) in Nigeria and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India mobilize international scientific resources to work on crops and growing conditions of agricultural regions that have typically been under-researched in the past and are characterized by low inherent productivity. Many of these areas also are experiencing population growth rates in excess of food production growth rates, and have become regular net food importers in recent years. For many of the countries falling into this category, the rise in food imports has taken place in a period of very slow growth or even decline in per capita income and cannot be interpreted as a result of economic progress. The failure of supply to keep pace, however, cannot be completely ascribed to inherent production limitations of the land, since policy disincentives and institutional shortfalls in promoting what improved technology is available have been important contributing factors (World Bank 1981).

Taking account of these contemporary differences, the key to whether or not a country (or region within a country) faces a problem of population pressure against the food yield is the relationship between the rate of growth of effective demand for food (including own-consumption demand in subsistence areas) and the rate of increase in average productivity per unit of arable land, at the point where all remaining uncultivated land has a lower yield potential than the average of the area already cultivated (or, more realistically, yields rapidly diminishing returns in relation to the average after the second or third harvest, under given farming practices). Growth in effective demand that derives from non-food sector income increases may be generated by efficient economic activities that simultaneously augment food import capacity, thereby helping, not worsening, the food/population relationship. In addition, the existence of an underlying deterioration of the relationship must be observed as a secular development. A. Sen has demonstrated that catastrophic supply failures and/or foodgrain price increases may result from interventions in the market or temporary falls in own-consumption output and/or money income that expose masses of people to catastrophic effective demand decline not offset by compensation mechanisms (Sen 1981). They have not resulted from sudden accelerated deterioration of the basic land/man ratio. Thus the simple comparison of domestic food output with population size at one point in time, and the labelling of the output as the carrying capacity for the relevant area, can be quite misleading.

Similarly, when comparing two points in time it is necessary to compare both the food production/population relationship and the food consumption/output relationship. Under modern conditions, it is artificial to treat the food production sector as if it completely determines consumption.

In sum, the closer a low-income agricultural region or country is to having no trade, only marginal technological improvements available for adoption, no effective institutional base for spreading such improvements as are known and warranted, no vent for surplus in the face of declining marginal returns to incremental arable land, and population growth more rapid than productivity growth, the closer it is to the simple model of a country approaching its carrying capacity ceiling. In fact there are numerous examples of regions that exhibit some of these characteristics, not absolutely (for example, virtually no areas are left in the world that trade nothing) but to a degree sufficient to keep these adjustment processes to a low level of efficiency. As Gould stressed, the key is the speed with which the constraints are pushed back.

Contemporary Cases

Scanning the countries that appear to be candidates for land pressure problems of a serious order, we find that they fall into different categories with rather different processes, consequences, and policy options for each:

1. Countries--largely agricultural--in which the weight of the factors discussed above is unfavorable and population growth in relation to productivity growth has already run a course long enough to bring about secular deterioration in the population/capacity relationship, or at least signs of a fragile balance, and where the problem is general throughout the country.

2. Countries in which these conditions are confined to a major "backward" region. An inherently low-density carrying capacity area (with poor endowment, little accumulated research, and less infrastructure and

accumulated capital than more favored regions) has undergone population growth long enough so that all traditional adjustments for raising outputs have been outpaced by labor force growth. Income decline and division of land into marginal sized units is being avoided (or softened) by out-migration to other areas of the country.

3. Countries in which high-density, well-endowed regions are experiencing population pressures, although the long-run prospects (given application of known technologies and likely results from accumulating research) are that these regions will have higher carrying capacities at higher income levels than is presently the case. Population is migrating out of the well-endowed regions during what might be considered a transition period in these regions, and is settling in previously thinly inhabited regions of low carrying capacity. Since the latter were not populated in the past and were not undergoing much development before, they have much less infrastructure than the regions from which the migrants are emanating, and little history of agriculture technology development. The carrying capacity problem is emerging in the region of in-migration.

4. Countries where traditional adjustments to land pressure have been hindered or eliminated by political changes that reduced the relevant (cross-border) area in which these populations had previously exercised adaptive strategies. (For the past decade the reverse process has been operating in the Middle East, where the labor requirements of construction programs in thinly populated countries offered a new cross-border outlet for rural inhabitants in substantial numbers from countries experiencing land pressure.)

Taking the third case first--the poorly endowed region receiving spillover in-migration--it would be logical to expect that migratory or sedentary populations historically occupying large areas relative to their numbers would tend to concentrate (unless forcibly prevented) in areas more, rather than less, benign in terms of their food potential, leaving substantial areas open for thin occupation, grazing, and other uses where the effective land areas per capita would be much higher than in the favored areas. As population begins to rise rapidly under modern conditions (for example, through public health interventions), density would start rising in the better area and various economic and social adjustment processes would be set in motion, including out-migration. This model roughly describes what has been happening in Pakistan, Nepal, and parts of Africa.

Kenya is an interesting case because of its historic experience and the clear evidence of present land capacity pressures. In the half century before independence, a major economic problem from the perspective of the colonial administration was the need to induce African labor to move from independent cultivation in relatively poorly endowed areas to wage labor in the agriculturally superior highlands (and urban areas). Since the 1960s the situation has reversed. The African population, no longer able to be accommodated in the former "white highlands" and higher potential areas, has been migrating into areas of low agriculture potential (and urban areas).

The transition really began artificially when the colonial government imposed the reserves system early in the century. To ensure adequate land for incoming settlers, the government drew boundaries restricting land availability for indigenous inhabitants. This policy ended the previous adaptation of the Africans to their environment under which a land-extensive, shifting cultivation, and animal husbandry regime could expand and move into unsettled areas. Faced with declining soil fertility as continuous cultivation combined with population growth in the 1920s, the African population had to respond to the wage labor, seasonal residence system to avoid the income decline that would otherwise have resulted. High density in relation to carrying capacity of the designated African areas has been created by fiat. In addition to male out-migration to wage labor in the European areas, the adaptation took the form of double-cropping and an increase in the work burden for the women who remained in the reserve areas. Colonial policy also concentrated agricultural research and infrastructure investment in the European settlement areas and on export crops (Faruquee and Gulhati 1983).

Kenya is also an interesting case because its extraordinarily high rate of population growth (probably 4 percent per annum) has drawn attention to the effects of that growth on the country as a whole. It is possible to separate some of these aggregate effects from the low-capacity region effects, enabling us to identify effects on overall development arising specifically from the growing population pressure on the low carrying capacity regions.

Projections of incremental investment and social needs Kenya will have to absorb over the next 20 years to avoid deterioration in per capita standards have been made by several authors. They are examples of the general literature on effects of population growth that fall into the category of duplication costs for incremental student, labor force, or other population groups; these costs absorb resources that otherwise would be available for capital deepening and increasing the quality and extent of services for the population that would be served by larger per capita resources were that population smaller by specified numbers at some future date. For example, a World Bank study has projected the incremental costs to Kenya of providing basic education, health, housing, and water services (merely duplicating present per capita levels and populations coverage ratios) up to the year 2000 from higher versus lower rates of population growth, and examined the negative effects on overall savings (World Bank 1980).

The profile of Kenyan land resources, its potential production from arable land divided into high, medium and low potential, and the relation of population size to future food needs, have been the subject of study by the Kenyan Government and the World Bank, among others. One exercise (by the World Bank in 1973) similar to the FAO/IIASA approach estimated the maximum rural population that could be supported, province by province, at a given income level per farm. It indicated that, for the country as a whole, only 3.7 million more people could be supported in rural areas compared with their actual 1972 population. For the year 2000, the Ministry of Lands and Settlement made a separate estimate of maximum carrying capacity under more optimistic assumptions (a higher level of income and a rate of growth in agriculture productivity twice that of the 1972-77 actual). This study implies that the rural population will be in excess of the carrying capacity by 6.5 million, a very sharp deterioration over a mere 28 years.

What is not clear in such studies is that, while the long-run outcome is posed as a possible future, with varying end results depending on which assumptions turn out to be correct over time, there are immediate costs and inefficiencies making the transition period more difficult than it would be overwise. These incremental costs arise from the fact that the poorly endowed or low-potential areas will yield lower returns to resource inputs than would be gained if the resources were invested in the high-potential regions.

There are various forms of diversion of resources that ignore the normal efficiency search for allocations that will maximize returns at the margin. In the allocation of scientific research in agriculture, for example, a serious effort to extend into Kenya's semi-arid areas was begun only in the late 1970s. Until that time, virtually no field work in these areas had been done on crops under study at the central research facilities near Nairobi.

Little was known about the growth characteristics of drought-resistant crops at the different zones of rainfall, average temperature, elevations and soil found in different parts of the semi-arid regions. With inherently poorer conditions, large requirements for soil conversation, and limited water retention possibilities, it would be extraordinary if returns to the research resources equaled what might be gained from their application to further research in higher potential areas.

Another immediate cost was the diversion of external aid funds to these low-potential areas. With the increasing donor desire to focus their efforts on the relatively disadvantaged, aid resources began to shift to projects in the semi-arid areas. In the late 1970s the government encouraged donors to focus on these areas and created special coordination arrangements to plan for the development of the areas and to organize donor support.

Under present agriculture technologies, capital invested in the semi-arid regions is likely to produce relatively low returns. Highly differential yields have already been documented within the small-scale farm sector which, as a whole, has shown the same higher output per acre than the larger farms, as has been observed in many countries. However, a small fraction of smallholders, whose farms are located in high potential areas, have accounted for a large fraction of the growth in the sector (World Bank 1980, p. 54). As the small-scale sector expands into the low-potential areas, the sector's overall growth is likely to decline, and may already have begun to do so.

According to a study done in 1978 by the Ministry of Agriculture, the government was well aware of the low returns to farming and livestock investment in the semi-arid areas at the state of technology available at the time. Comparison of specific projects in the semi-arid and high-potential areas showed substantially higher returns in the latter, and returns in the former barely sufficient to justify the activity.

Besides the loss in growth implicit in this resource allocation process, studies of semi-arid settlement have shown that the unadjusted application of traditional cultivation techniques in these fragile areas is causing rapid degradation (World Bank 1980, p. 55). Squatter migrants are adopting the fallow-reduction practices noted above, with possible irreversible effects for future cultivation.

Under modern political conditions in many countries, it is impossible for governments to ignore the income differentials and relative poverty conditions of populations residing in such areas. The Kenyan government is among those providing consumption support to inhabitants of such areas, the extent of the transfers reflecting year to year differences in harvest conditions. To the extent that public sector funds are allocated to regional consumption support in these areas of in-migration, the funds represent foregone investable resources, another immediate cost to overall development. Since years of very low rainfall are recurrent and characteristic of the semi-arid regions, relief operations are likely to be a regular charge on government resources, probably increasing over the years as the population settling in these areas continues to rise.

The category of the already filled-up, low-potential region with many of the signs of pressure against carrying capacity, includes areas with very substantial populations. This category differs from the previous in time perspective; the poorly endowed regions have been well populated for some time as modern development got underway. These areas comprise the "backward region" problem of northeast Brazil, northeast Thailand, southern Italy, the "barani" districts of Pakistan, and other countries.

The example of Thailand is interesting because population pressure against carrying capacity was identified 25 years ago by a major World Bank country study team effort (World Bank 1961). The team noted that the long vent for surplus process in Thailand's Central Plain rice delta was coming to its inevitable end, and that unless productivity were raised the country's exportable surplus of rice would be absorbed by increasing domestic consumption. This projected outcome has not come to pass. Irrigation works and changes in technology have enabled the delta to substain both exports and the domestic needs of a population two-thirds larger than it was at the time of the World Bank study, while also diversifying into a variety of commercial crops and enjoying a healthy rise in income. Thus the Central Plain is a region that has successfully avoided the pressure against carrying capacity that appeared to be a reasonably possible short-term outcome not very long ago.

Northeast Thailand was at that time, and remains today, the poorest region of the country, with about one-third of its population. While out-migration from the Northeast remains a net contributor of population to other regions, it has also participated in the overall growth of the Thai economy over the past 25 years. The main factors contributing to this record, in the face of a poor soil and water endowment (and virtual total absence thus far of any mineral or other resources), have been the gradual deforestation and cultivation of the diminishing residual land areas within the region; increased non-agriculture wage labor; shifts into new crops as improved physical access and relative price increases made their cultivation more profitable than traditional crops for own-consumption (although production of the preferred glutinous rice for consumption in the Northeast continues as the core subsistence activity). The region benefited from linkages with the rest of an economy experiencing rapid economic growth, and with a vigorous export-oriented market system. It has also benefited from remittances and probably from net transfers through the public sector, although evidence on the latter is poor.

Rising regional income and output have gone hand in hand with rising population density. It would be a mistake, in this writer's view, to conclude that population pressure against the carrying capacity of the region was merely an arithmetic artifact, and that the region has been an example of how population growth can be a stimulant to income growth. The process of forest clearing and bringing marginal lands under cultivation has ground forward to the point where little scope is left in the region for further extensive output growth. Forest cover fell by one-third in the 17 years between 1961 (when forest comprised 53 percent of Northeast land area) and 1978 (34 percent), and by another half in only four years (to 15 percent in 1982). (For the country as a whole, Landsat data have revealed an alarming drop in forest cover due mainly to population encroachment.) The prospects for raising carrying capacity further are still poor although the problem has been given much attention by the government and aid donors during the past two decades. Investments in irrigation--only 15 percent of the arable land is irrigable--have produced very disappointing results, while research has yet to yield significant breakthroughs in agricultural technology for the different semi-arid, poor soil, erratic rainfall conditions of the region. Barring such breakthroughs, the Northeast could be approaching the internal region ceiling constraint implied by its rising man/land ratio, although the constraint could continue to be ameliorated by out-migration, remittances, net government transfers, and other linkage effects.

Labor force characteristics in northeast Thailand illustrate the importance of the caution suggested earlier regarding drawing misleading conclusions from the simplifying assumption that capacity problem regions are closed and completely agricultural. The constraining environmental conditions of the Northeast compress the agricultural work periods into long-hour work weeks during the short wet season and harvest periods (Bertrand 1980). This pattern allows considerable scope for the labor force to participate in off-season agricultural work in other regions, or in non-agricultural work, both within the Northeast and elsewhere. The very disadvantage of the time constraint on Northeast cultivation opens the possibility for loosening dependence on the land itself of that region. Unfortunately for the extra-regional employment options, however, overall growth of Thailand's labor force will enter its peak decades in the 1980s and 1990s, reflecting the high birth and survival rates of the 1950s and 1960s. Thai planning authorities expect the growth in non-agricultural employment in the near term to fall well short of increases in the labor force seeking employment outside agriculture.

The "barani" districts of northeast frontier and northern areas of the Punjab in Pakistan are another example of evident population pressure against a constraining environment. Containing about one-sixth of Pakistan's population, these areas of limited and irregular rainfall have long been characterized by out-migration and poverty. Since Partition, symptoms of this pressure have been the diminishing average size of holdings, and increased fragmentation. New proven agricultural technologies have not been available, nor have new extension and input systems been adequate to ease the inherent production constraints (Lieberman 1981).

The small category of countries whose carrying capacity problems have been created by political change--for example, by recent boundary establishment--will not be examined as a separate group in the context of this paper. Nor will we examine the recent group of countries whose rising density had been relieved temporarily through organized worker migration, countries that may now face reversed movement due to slackening conditions in the receiving countries. Neither of these categories is distinct in terms of the internal characteristics of their density problems.

We also note briefly the carrying capacity problems of very thinly populated, very arid areas inhabited by nomadic pastoralists. The carrying capacity of these lands is measured in terms of animals rather than crops. Simultaneous growth of human and herd populations have resulted in overgrazing, compounded in the Sahel by the water and vegetation stress during the usually dry years of the early and late 1970s and again in the past couple of years. The capacity concept in its relatively simple form applies to these areas. Technologies for fundamental easing of the constraints to income growth, as human population continue to rise, are not in sight, and might in any case require infeasible investment levels.

An example of the difficulties of attempting to transplant outside ideas on reorganizing a pastoral system was the program in the 1970s in Kenya's very arid Northeast. New waterholes, a government maintenance and oversight system, and new arrangements among pastoral groups for rotational use of grazing areas were among the innovations introduced to help the pastoralists increase their production for sale to the cattle markets in the central region of the country. The administrative, social, and technical problems encountered were judged so formidable in an evaluation, that it recommended limiting the program to a maintenance concept, abandoning an effort to increase the animal population, and relying more on the experience of the pastoralists themselves as how to best survive under the conditions in which they have had long adaptive success (Devres Inc. 1979).

Under such fragile conditions and formidable obstacles to an easing of the land's physical output constraints, it is hard to see any methods for even maintaining per capita income levels short of out-migration, permanent income support from outside the region, reduction in fertility to maintenance levels, or some combination of these. Where the population of such areas comprises a small fraction of the total population of the country (as in Kenya), successful long-run growth of the country as a whole may enable it to afford the internal transfers that the social and political conditions of the Northeast may necessitate. Where such populations comprise a large fraction of a country's population, nothing short of rapid reduction in fertility appears to offer long-term escape from permanent dependence on international transfers or possible return to a regime of higher mortality.

The remaining category--countries whole entire arable land area is under cultivation, and whose largely rural population is trapped at low income levels with further additions to population increasing food demand faster than its agriculture can meet at maximum yield--appears to have few members. Bangladesh may have the popular image of a country whose dense and rapidly increasing population is fighting a marginal battle for sheer ability to feed itself at one of the world's lowest levels. The country's need in most years for imported foodgrains and the rising proportion of landless population in rural areas may appear to be symptoms of a straightforward population expansion that has gone beyond the country's carrying capacity. In fact, the extent and causes of landlessness in Bangladesh are unclear, but the recent additions to landlessness may have resulted from waves of land selling following each of the country's weather catastrophes that forced many to sell their assets for cash for immediate consumption needs, and not from a secular process of subdivision squeezing people off increasingly crowded holdings (Cain 1981). In any case, yields in Bangladesh are well below the levels that could be obtained under current technologies. The constraints to current production are economic and institutional, not inherent agronomic limitations. Thus it would be a misspecification of Bangladesh's population/resources problems if carrying capacity limits were thought to be so inherently constraining that the full burden of the development problem was ascribed to population growth. This is not to say that population growth is not a serious drag on the country's economic development, but merely to suggest that careless application of the carrying capacity pressure image is not useful in this case as a guide to understanding the country's position. It is the institutional and economic problems--for example, the capital costs of expensive water management investments needed to exploit the land's potential--that pose the real constraints on the country's capacity to achieve higher food production levels.

Finally, it is important to note the larger environmental sense in which population growth may be said meaningfully to be pressing against a region's carrying capacity, food production aside. Where the fuel technology of a rural population depends on culling firewood from the local vicinities, rapid population growth has been raising the rate of forest destruction beyond the rate of natural regeneration. This problem has been widely described in recent years and has led to some increases in priority and effort in the forestry sector by governments and development agencies. Haiti is often cited as the country where the process has led to total deforestation. Some rapid deforestation has been caused by commercial exploitation rather than population encroachment, for example, in eastern Malaysia. In cases like Nepal, however, it is clear that population growth is directly responsible for the extensive deforestation for fuelwood that is having profound effects on Nepal's economic development and on the hydrology of the Gangetic plain. In the Sahel, deforestation for fuel induces expansion of the desert. This destruction of productive area may be irreversible. Reforestation in the Sahel has barely gotten underway and faces difficult obstacles (World Bank 1982). Without successful intervention and reversal of these trends, the deforestation resulting from carrying capacity pressures could itself contribute to more rapid deterioration in the regions' support capabilities through its soil erosion and other effects on the physical basis of food production.

Some Policy Considerations

We have stressed that the population/capacity problem commonly appears as a depressed or backward region problem. The Kenyan and Thai examples, and the record of developent efforts in northeast Brazil and southern Italy, show that the backward region problem poses a dilemma for development policy. Prior to the time when breakthroughs in technology or other fundamental changes in a region's endowment or relative cost structure shift a reigon's inherent relative profitability for economic activity, public sector expenditures in the region may yield low returns for both the region and the country. By pressing more rapid growth in better endowed regions, all areas may be better off. Examples of substantial investments in very low-yielding irrigation projects in northeast Thailand, financed partly with funds from several donors, illustrate the foregone benefits from a policy of seizing even questionable project options that satisfy a government's need to demonstrate non-discrimination against one region and donors' desire to direct assistance to the lowest income beneficiaries (Muscat 1982). The equity problem is particularly troublesome, since the poorest segments of the population in such countries (including the four cited above) not surprisingly are those residing in the most poorly endowed agricultural regions.

The lagging backward region problem does not appear to have gotten the analytic attention it deserves as a kind of dualism. The "foregone deepening" cost of population growth is normally calculated as a function of replication requirements for increased numbers of the population as a whole, as in the Kenya example above. These opportunity costs also have a spatial replication aspect that is highlighted when spatial consequences of population growth are examined. If spillover migration into poorly endowed, sparsely settled regions had been (or could be) avoided, substantial subsequent capital allocations for transportation, commumications and other infrastructure could also have been avoided. Even if these duplication investments only could have been postponed, as a function of slower filling-up the additional yield for development in the interim from capital deepening in the better-endowed areas could be substantial.

Lagging regions often suffer from social and political disabilities that compound their resource limitation problems. Even in those countries where the backward region has been well populated for some time, there are substantial gaps between the levels of amenities and schooling available in the advanced and lagging areas, and between the opportunities for career advancement and professional satisfaction. Under these conditions it is difficult for government to attract first-class personnel to the lagging region. The industrial sector may also neglect the region, not only for the problems of attracting employees, but for the economies of location in the favored region, increasingly fixed as the disparities between the areas widen.

It is not inherent in the development process that all areas are equal, at any stage of technological development, in their return to the application of scarce resources. The most efficient strategy for generating increases in income in the pressured region may be to concentrate on growth in the higher-potential areas, promote systems of seasonal or permanent migration and facilitate remittances, promote and strengthen linkages through which growth of the more dynamic areas can pull along the backward areas, invest in the long-term buildup of the human capital of the region to open up any potential the region may have for freeing itself from dependence on its natural resource base, and develop tourist industry potential (the very agricultural limitation may go hand in hand with natural beauty). Of the largest numbers of a region's inhabitants in the near term, if the technological limits to carrying capacity can be raised, agricultural research should be given high priority. But large-scale capital projects to raise agricultural yields before improved technologies are in hand, or to induce industry to locate in a region despite its cost disadvantages, should be avoided if possible.

These would seem to be the elements of strategy for a poorly endowed region experiencing carrying capacity pressure. To explore them further would go beyond the terms of this paper.

Even though family planning programs cannot be expected to affect labor force growth until at least 15 years in the future, there may be demographic processes at work in the most extreme carrying capacity situations that argue for urgent need to begin immediate measures to lower fertility. In Nepal one analyst has suggested that the persistence of high fertilty in both the out-migration hill areas and the in-migration terai may be attributable to a rise in the economic value of children because of the breakdown of traditional communal support and environmental monitoring in the former areas, and the absense of such arrangements among the heterogeneous communities in the latter (Lieberman 1982). Density is itself bringing about social changes that may strengthen private perceptions of benefits from large families.

Another example where private judgement of the utility of a large family is at variance with social utility, in a situation of short-run deprivation, has been suggested in Bangladesh. Long-run potential considerations (as argued above) aside, the short-run perspective of individual families facing recurrent weather catastrophes may well put a high premium on risk aversion in a marginal economic situation. Based on a study of Bangladesh after the 1974 famine, it has been hypothesized that populations (that is, families) living with the high economic and mortality risks associated with recurrent threats of famine may sustain high fertility longer than other populations living in less unfavorable environments that have begun to alter their fertility behavior in the past decade. The effort of individual families to reduce diaster risk has the cumulative perverse effect of worsening the relationship between population and the resource base. If risk defensive behavior also leads to inefficient adaptive responses--for example, a forshortening of fallow periods, resulting in declining soil fertility and lower food production--the area involved would be caught in a "vicious circle" of increasing pressure on capacity.

In contrast with these cases of possible fertility-increasing responses to population pressures in difficult environments, there are other examples of areas (of both very low and medium levels of per capita income) where high density itself, or more accurately the perception of high density in relation to economic circumstances, may have triggered deliberate fertility regulation. For densely populated areas experiencing carrying capacity pressure, this is an interesting possibility, worth more research than has been directed to it thus far.

The observation that small island countries began to experience early fertility decline compared with other developing countries was made a number of years ago by Paul Demeny. It is tempting to draw a parallel with the psychological and educational aspects of the family planning program in east Java, where villagers are reluctant to leave their traditional local areas. The family planning information and education effort includes village mapping and tracking of village population density for years in the past to increase everyone's awareness of the growing numbers of people who have to be housed and supported within the same village vicinity and land support area. The Chinese family planning program may also be facilitated by the limits imposed on people's movement. In all these cases, the fact that population increase is not readily exported to areas away from the home economic unit means that pressure against the productive capacity of the local income base is "internalized" in the community and the family, perhaps along with a sense of rising crowding. Without going so far as to propose "command" population policies, it does appear that the "island" fertility phenomenon may be worth more analysis than it has received, with its possible implications for community level family planning education and for community incentives that would match fertility reduction with localized benefits.

Finally, once the extremely limiting assumptions surrounding the concept of carrying capacity for one region or country are made explicit, it is clear that no simple one-dimensional policy conclusions should be drawn from capacity measurement exercises. Considerations of food security, comparative advantage, or income distribution often lead to a stress on high rates of growth in food production. Certainly that portion of the labor force that is engaged in food production should be helped to increase its productivity. It does not follow automatically, however, that every country experiencing declining per capita food production should focus development policy around the objective of food autarchy.

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CARRYING CAPACITY, POPULATION GROWTH, AND SUSTAINABLE DEVELOPMENT

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Abstract

The concept of carrying capacity is familiar to biologists and wildlife managers concerned with the ability of ecosystems to support animal life. It is defined for a particular region as the maximum population of a given species that can be supported indefinitely, allowing for seasonal and random changes, without any degradation of the natural resource base that would diminish this maximum population in the future. With some modifications, carrying capacity can also be used as a measure of a region's ability to support human populations. It is, therefore, a useful concept for the work of development economists, planners and political decision makers.

In contrast to animal life, human populations can expand the carrying capacity of a region to a great extent through technological advances and trade. Neither technology nor trade, however, can permit unlimited population growth. Moreover, it is often easier and cheaper to exceed temporarily the carrying capacity of a region through environmental mismanagement. The latter response to carrying capacity constraints, while allowing short-term increases in the per capita supply of goods, is not sustainable in the long-run and may ultimately cause irreparable damage to the natural resource base. Examples of human-induced reductions in long-term carrying capacity discussed in the text include deforestation, desertification, loss of biological diversity, and pollution.

The paper concludes that many developing countries have paid insufficient attention to policies to lower their population growth rates--relative to policies to expand sustainably their carrying capacities--as a means of bringing population and natural resource availabilities into balance. While both options are necessary, it is particularly urgent that vigorous population policies be adopted in those developing countries already suffering severe problems related to environmental and natural resource degradation.

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The Concept of Carrying Capacity

The carrying capacity of a particular region is the maximum population of a given species that can be supported indefinitely, allowing for seasonal and random changes, without any degradation of the natural resource base that would diminish this maximum population in the future. The concept of carrying capacity is familiar to biologists and wildlife managers, who devised it to express the capacity of natural areas (ecosystems) to support animal life. With modifications, it is also an important measure of the ability of regions to support human populations. Carrying capacity is, therefore, an important concept for the work of development economists, planners, and political decision makers.

In the study of natural ecosystems, application of the carrying capacity concept is relatively straightforward. For example, the number of deer that can survive in a temperate forest may be determined by the availability of winter browse. In such a case, if too many deer are born in any given year and the surplus is not removed by predation, disease, or other means, winter starvation will reduce the population to the forest's carrying capacity. In other words, the deer population is constrained by the availability of food in the winter.

In ecosystems managed by humans, defining and measuring carrying capacity is essential for sustainable natural resource use. On managed rangeland, for example, humans have controlled the predators that would have limited the population of grazing animals on natural rangeland. Consequently, ranchers must assess the carrying capacity of the range and control the grazing herds accordingly. If the herd size exceeds the long-term carrying capacity of the range, immediate starvation (as in the case of the forest deer) is unlikely. Instead, the animal production of the range probably will increase for a brief period. Over the short term, more grass will be converted to meat. Over the long term, however, overgrazing will interfere with the reproduction and growth of the range grass, ultimately causing irreversible damage to soil productivity, thereby reducing the number of animals that the range can feed. Overgrazing boosts animal production briefly, but it does so at the expense of permanently eroding the carrying capacity of the rangeland resource base.

As this example illustrates, it is usually possible to exceed the carrying capacity of a region temporarily. A renewable resource base cannot sustain a population beyond its carrying capacity indefinitely, however, and will suffer a reduction of its inherent productivity as a result of being overexploited. Managing such resources is difficult because the decline of the carrying capacity is usually evident only some time after the damage has been done, and because over the short term the productivity of the resource has actually increased.

A useful analogy is an interest-bearing bank account. The "carrying capacity" of the bank account is the interest. It is possible to siphon off the interest without impairing the account's ability to produce more interest. However, if money is withdrawn from the account faster than it is being generated (thereby temporarily increasing the "yield" from the account) the process is unsustainable, as the future "carrying capacity" of the account is reduced. Similarly, the carrying capacities of some ecosystems can be exceeded for a while, but they cannot be exceeded sustainably.

Thus far, this discussion of carrying capacity has considered only one kind of resource, food. Food availability readily comes to mind in discussions of carrying capacities of developing regions, since it can be a constraint to population growth. However, in highly concentrated urban centers (if food is readily available through trade with outlying areas), the carrying capacity is often determined by other factors, such as the availability of living space or the ability of natural or human-designed systems to dispose of wastes and pollutants. In other areas of the world, future population growth may be constrained, not by the supply of food itself, but instead by the availability of fuelwood to cook it. A region's carrying capacity is ultimately determined by its scarcest vital resource.

A region's carrying capacity exists for humans, as it does for every other form of life. To date, little effort has been spent on defining and measuring the human carrying capacity of natural systems. Applying the carrying capacity concept to humans is also complicated by several factors. One such factor is the fact that per capita natural resource consumption by humans is often extremely variable, whether within the same society or among different societies competing for the same natural resources. Another complicating factor is people's ability to control, to some extent, the natural resources upon which they depend. Unlike other species, human beings can expand the carrying capacity of their environment by using technological innovation and trade. However, humans can also diminish the carrying capacity of a region through various forms of environmental mismanagement leading to long-term natural resource degradation. Such human-induced degradation often results from various short-term human pressures, which occur largely in response to rapid population growth. These points are elaborated in the following three sections.

The Role of Technology

Through technological change, humans can increase the productivity of natural resources, thereby expanding the carrying capacity of a region. Technology can increase the carrying capacity of a given region in two ways. First, it can allow people to substitute, to some limited extent, a natural resource that is abundant for one that is scarce. Fertilizers, for example, allow farmers to compensate for a shortage of arable land by applying chemicals that are not in short supply--at least until the petrochemical or coal feedstocks used to synthesize many of them become too expensive. Second, technology can increase the efficiency of conversion of natural resources into economic goods, thereby allowing people to "squeeze" more economic value from a given natural resource base.

While technological advances can expand the carrying capacity of a region to a considerable extent, they ultimately reach diminishing returns and do not make unlimited population growth possible. For example, at high application levels, fertilizers exhibit sharply declining marginal returns and cause serious environmental complications (such as eutrophication of lakes and health-endangering nitrate levels in drinking water). At some point, increased fertilizer use will result in nutrient "poisoning" of crops and an actual drop in yields. By contrast, some production functions used in economic analysis (such as the Cobb-Douglas function) assume that factors of production are infinitely substitutable for one another, and that using any resource more intensively guarantees an increase in output.

Moreover, technology cannot increase the total quantity of natural resources ultimately available on this planet. It cannot create more raw materials out of nothing--nor can it increase the efficiency of conversion of these materials into economic goods beyond the constraints imposed by the physical laws of thermodynamics. For example, intercropping or rotation cropping of compatible species can result in greater food "outputs" from the same farm "inputs", but no conceivable combination of technologies could produce more food energy "output" than was available as (solar and other) energy "input" to the farm. Therefore, no technological advance can eliminate natural resource constraints entirely. Furthermore, technology cannot increase the Earth's natural waste assimilation capacity, although it can be used to reduce the volume of pollutants or other wastes that are generated. Thus, while technological advances can expand a region's carrying capacity to some extent, they cannot replace the need for eventual population stabilization. In the shorter term, the rate of population growth cannot exceed the rate at which technological advances increase carrying capacity without reducing people's standard of living and risking an overshoot of the carrying capacity.

China provides an example of both the potential and the limitations of improved technology for expanding carrying capacity in terms of food production. In China, the carrying capacity has increased substantially as the intensity of food production has risen and new management practices and technologies have defined more productive agro-ecosystems. For example, in a pastoralist China, one hectare of grazing land could support only 1-2 persons. Traditional farming with careful recycling of organic fertilizers raised the carrying capacity to 5-6 people per hectare. Today's cultivation, relying increasingly on large inputs of nitrogenous fertilizers, can sustain 10 people per hectare as the national average; in Sichuan, China's most populous province, 17 people are fed from each hectare.

Carrying capacity has thus been raised impressively over the past several thousand years in China. However, as some constraints to food production were removed (for example, dieback of herds during cold winters or crippling pest damage to crops), new ones have emerged in their place. Today, China's carrying capacity rests critically on the availability of fossil fuels and electricity that provide synthetic fertilizers and pump the water needed for new, high-yielding crop varieties.

Carrying capacity is not an immutably fixed number, Proper management of areas endowed with suitable soils, moisture, and growing season can raise carrying capacity by minimizing or even removing old constraints. But new constraints always emerge, and even in the best croplands there is a limit to continuous, steady improvements. Moreover, areas of marginal or poor cropland are suffering from severe soil erosion and degradation, deforestation and a resultant increase in flooding, desertification, and toxification. Such environmental stresses suggest that the carrying capacity of these regions has often been reached; even the best available practices may not be able to accommodate all of the people living in such stressed regions.

The Role of Trade

Another means of pushing back natural resource constraints is trade. Trade can expand local carrying capacity by exchanging resources that are locally plentiful for those that are locally scarce. For example, countries in the Persian Gulf can support populations far in excess of their local agricultural carrying capacities by trading oil for food. Similarly, city-states such as Singapore and Hong Kong support population densities roughly 100 times higher than the local carrying capacity by paying for food with the value added to labor-intensive goods. In other words, trade allows one region to make use of the excess carrying capacity of another.

Trade can expand local carrying capacities only in certain circumstances, however. The resource that is scarce in one region (for example, food) must be available in surplus elsewhere, and the region's plentiful resource for (example oil, phosphate rock, or cheap labor) must be scarce elsewhere. Trade cannot alleviate global scarcity, as there is no other "globe" nearby with which to trade! The difference in value between the exported and imported goods must be enough to pay the costs of transportation both ways, which for small, remote, or landlocked countries (or those lacking good internal transportation) can be enormous. Transportation costs are a particularly great obstacle to commerce in high-bulk, low-value commodities such as food staples or many raw materials. As fossil fuels become more scarce and their cost rises, many opportunities for trade are likely to become uneconomical because of higher transportation costs.

Finally, there is a distributional issue that is easily overlooked if the country is treated as the basic unit of analysis. The foreign exchange earned by the exports must somehow find its way into the sectors of the economy that need the imports in question. For example, if rural people export cash crops rather than growing their own food, distribution mechanisms are needed to ensure that these people will be able to buy enough food to meet at least their basic needs.

The examples of Singapore and Hong Kong, which survive by marketing the value added to goods by human labor, deserve special attention. Many nations would like to emulate their relative affluence, despite their high population densities and lack of exploitable natural resources. Of the many countries that would like to be the next Hong Kong, any one could conceivably succeed. But they probably cannot all succeed in doing so, because there does not seem to be a sufficiently large, unmet global demand for human labor to add value to goods. With unemployment at relatively high levels in even the world's most affluent countries, and with population growth swelling the world's labor force every day, it seems unrealistic to expect that most of the Third World will be able to solve its carrying capacity problems by marketing its surplus labor through international trade.

Human-induced Reduction of Carrying Capacity

Societies display two very different patterns of adaptive response to carrying capacity constraints. The first is to bring the population and the carrying capacity into balance by limiting the former or, more commonly, expanding the latter. The second pattern of adaptive response is to exploit the resource base beyond its carrying capacity (akin to "deficit spending" in the bank account analogy), thereby liquidating natural capital for one-time use.

It is difficult at first to distinguish these two patterns of adaptation, because their short-run effects are superficially similar. In both cases, the supply of goods per capita increases in the short run. But the difference between the two approaches is crucial. The first is sustainable, while the second damages the long-term carrying capacity. Recognizing this difference is both difficult and vital, because any damage is likely to be apparent only after a substantial time lag and after it has become largely irreversible.

When populations press against or exceed the limits of their natural resource base, they are driven by their circumstances to patterns of adaptive response that are not sustainable. It is cheaper, in the short run, to exploit a resource base beyond its carrying capacity than it is to expand the carrying capacity or to limit population growth. Populations that have reached their upper limits, and whose surplus resources are in critically short supply, will adapt to their circumstances in the cheapest possible way (particularly if the competitive market is the only mechanism of adaptation). In so doing, they will ultimately decrease the productivity of their natural resources, and thus generate even stronger pressures for the same counterproductive patterns or adaptation. The result is a downward spiral of resource productivity and living standards.

It appears from historical records that some of the world's most advanced societies have been destroyed by following the second path of adaptive response. There is growing evidence that the Mayan civilization vanished when population pressures caused deforestation and soil erosion, resulting in the collapse of its agricultural system (Deevey, *et al*. 1979). Valleys in Greece that once were the site of some of the most intensive irrigated agriculture in the western world will now support only scrub growth and grazing animals. During the days of Caesar, northern Africa was the granary of the Roman Empire; it has long since been unable even to feed itself.

Fortunately, science has provided the means for averting similar disasters. We can detect natural resource degradation in time. What is needed is the political wisdom to act on the signs that indicate that a particular pattern of development is not sustainable. Later in this paper, we detail some illustrative scenarios of local populations and carrying capacities that are, or soon may be, out of balance.

The Global Carrying Capacity Debate

Ever since the days of the British economist Thomas Malthus, the question of global carrying capacity has been a subject for lively discussion. Despite this debate, which has greatly intensified during the last decade, no consensus has emerged on this issue.

Some scientists, such as Westing (1981) and Mann (1981), argue that the world cannot sustainably support a human population of more than about 2 billion. Westing (1981) bases his calculation on such assumptions as:

(1) A global level of per capita consumption that is "affluent," that is, the average of those of the world's 27 richest nations.

(2) Existing levels of technology.

(3) Existing policies and practices of natural resource utilization, that is, no major changes in market or non-market mechanisms to encourage increased efficiency in natural resource use.

There are several reasons why the world is presently supporting a population that is substantially in excess of the carrying capacity, as defined by Westing and Mann. One is that a sizable proportion of the population does not have an "affluent" level of per capita natural resource consumption. Another is that nonrenewable natural resources,[1/] particularly fossil fuels, are being exhausted, thus enabling humanity to live "on borrowed time" in excess of its carrying capacity. A third reason is that renewable natural resources (such as soils, grazing lands, forests, and fisheries) are being overexploited at unsustainable rates, thereby temporarily increasing present production at the expense of future production.

At the opposite extreme are persons such as Simon (1981) and Kahn (1982), who insist that the world's natural resources are not meaningfully finite, or at least are sufficient to support unrestrained population growth

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[1/] Renewable natural resources include living resources (plants and animals) and other natural resources (particularly soil and water) that create or sustain life and that are self-renewing if not overexploited or otherwise mismanaged. Nonrenewable natural resources are not self-renewing. The include minerals (which can often be profitably recycled) and fossil fuels (which cannot). Care is also required in the extraction and processing of nonrenewable resources to prevent unnecessary environmental damage.

for centuries to come. To support these views, Simon and Kahn cite what they believe to be the huge size of the Earth's remaining natural resource base, the ability of technological progress to advance more rapidly than population growth, and the ability of market forces to automatically keep natural resources and the demand for them in balance. In this view, there is no need for efforts to stabilize population size.

In between these extremes are a variety of estimates of global carrying capacity. Some of these estimates are in excess of the most recent United Nations projections of future stationary population size. For example, Kovda (1980) has stated that in the view of some Soviet scientists, the world can support a population of 14 billion. On the other hand, other estimates are lower than projected future population size. Gilland (1983) suggests a global carrying capacity of 7.5 billion.

Aside from the poor quality of much of the available natural resource data, the principal reason for such huge discrepancies in global carrying capacity estimates (ranging from 2 billion to no limits) is the very different assumptions that are used. Among the pivotal assumptions that influence global carrying capacity estimates are the following:

(1) The rate at which advances in technology can sustainably expand carrying capacity, in comparison to the exponential growth rate of population.

(2) The size of the essential natural resource base.

(3) The extent to which market or non-market (political or social) mechanisms will ensure the efficient use of scarce natural resources.

(4) Levels of per capita consumption of natural resources.

As this controversy shows, the actual carrying capacity of the planet is unknown and perhaps unknowable. In the face of such uncertainty, it is most prudent to proceed cautiously. It would be inadvisable to rush headlong into a possible confrontation with our limits to growth, foreclosing options for the future along the way. Even if incontrovertible evidence existed that technological progress could continue to expand global carrying capacity, the rate of population growth must be no more than the rate of carrying capacity growth, if carrying capacity is not to be exceeded.

Carrying Capacity and Optimal Population Size

The global carrying capacity debate is one of how large the earth's population could become, not how large it should become. The optimal population size is not necessarily the same as the carrying capacity. Human population can be sustained at any level up to the carrying capacity of the natural resources that support them. A common assumption is that the population should be encouraged--or at least allowed--to grow just to the carrying capacity, and stabilize there. Implicitly, then, many people believe the largest possible population size to be also the optimal population size.

There is no a priori reason why this should be the case. Populations pressing against their carrying capacities are likely to have low standards of living and slim prospects for substantial socioeconomic improvement. The definition of what population size is "best" is inherently a matter of value choice rather than scientific facts. Many human values are, arguably, better served by a stable population size substantially below the carrying capacity.

For populations just at the limit of the carrying capacity, vital resources are in critically short supply. There is no surplus. Because resources are being spread among as many people as possible, per capita consumption of goods is at the lowest possible level. This realization demonstrates the fallacy of Bentham's crdeo, "the greatest good for the greatest number" (aside from the logical impossibility of double maximization). Moreover, it shows that the concept of carrying capacity embodies critical social choices.

Some people maintain that human welfare is essentially independent of population size. In this view, the productivity of each worker is a constant, so each doubling of the population will, by definition, double the productivity of the economy as well. This argument overlooks the fact that, as the population grows, the raw materials available from a constant resource base will provide fewer inputs per worker. Therefore, all else being equal, the productivity of the economy per worker, and thus the level of goods available per capita, must decline as a growing population approaches the carrying capacity.

The main implication of this analysis is that, beyond a certain population density, a fundamental trade-off always exists between further increases in population size and per capita consumption. To illustrate this point, Thomas Malthus stated that there should never be more people than can enjoy a piece of meat and a glass of wine with each dinner. This statement implies, of course, that population density should be sufficiently low to enable enough land to be used to produce such "luxury" products as meat and wine for everyone. While not all cultures place a high value on meat or wine consumption, the desire to consume at a level well in excess of bare survival needs is almost universal. People will disagree on the ideal choice between more people and a higher standard of living per person. However, if societies do not make such choices through population policy decisions, their population growth may proceed to a point where a large population with low per capita consumption is unavoidable.

Not only must conventional economic goods be shared by more people as the population grows, but "noneconomic" and "amenity" goods become scarcer as well. For example, open space, natural recreation areas, and wildlife become scarcer as more land is allocated to meeting the food, housing, and other needs of a growing population. Leisure time becomes more dear as more time is required for providing for basic needs (because, as noted above, the labor efficiency of the economic process decreases as natural resources become scarce). In the Gambia and central Tanzania, for example, population growth has made firewood so scarce that each household requires 250-300 worker-days to meet its annual fuelwood needs (FAO 1978, Moris and Openshaw 1979).

Moreover, as natural resources become more scarce, the administrative structure and coercion required to enforce efficient resource allocation increases. For example, allocation of irrigation water where it is scarce has long been a source of friction between nations and among factions within individual countries. Even when farmers have decided on a formula for dividing the water supply, they must also agree to coordinate all of their cropping activities. Greene (1966) notes:

> "Failure to observe these practices injures not only the individual farmer but his neighbors also; irrigation implies a uniformly high standard of farming; losses are severe if this is not kept up."

When populations press relentlessly against (or temporarily exceed) the limits of their local or national carrying capacity (no matter how much it is augmented by trade or technology), the development process can be crippled. Economic development depends upon the successful reinvestment of surplus resources. When a population reaches the carrying capacity of a region, such that all the region's available resources are supporting the largest possible number of people, all production is devoted to immediate consumption need. There is no surplus to invest for the future.

There are profound value judgments implicit in declaring any one population size as "optimal" for a given country or region. The only imperative is that no population can be supported sustainably above the carrying capacity provided by the available natural resources. Because population size and per capita consumption are ultimately constrained (at some uncertain limit) by natural resource availability, and because (in modern times) it is much easier to allow a population to grow than to force it to contract, the path of caution is to seek as little population growth now as possible. In so doing, we would foreclose the fewest lifestyle and resource use options, and preserve the widest range of choices for future generations.

Population Growth, Environmental Degradation, and Natural Resource Scarcity

When international development specialists discuss "the population problem," they are actually confronting two distinct, though obviously related, classes of issues. The absolute population size of some countries, or regions within countries, threatens their standard of living and the viability of their natural resource base. The rate of population growth of other countries and regions, even those with relatively low population densities, is sufficient to cause severe economic, social, and environmental dislocations, while foreclosing a range of options for the future. Even if a country's population size is well below its optimum level (however "optimum" might be defined), its rate of population growth may be well above the optimum.

It should be evident from the preceding discussion that the population size and population density of countries are not *per se* the causes of problems such as natural resource degradation or hunger. Rather, these problems arise when the population becomes too large in relation to the productivity of the resource base upon which it survives. Low population densities do not necessarily mean that carrying capacity constraints pose no problems. Most of the "empty quarters" of the world are empty for a very good reason: their resources cannot support many people. Africa provides perhaps the clearest example of how much of a seemingly "underpopulated" continent may, in fact, be too crowded.

Africa seems, at first glance, a vast and empty continent. But on closer inspection, it appears that many countries in Africa are becoming very crowded indeed. Africa has been described as "underpopulated" because its population density is relatively low. Compared with most of Asia or even Central America, Africa seems uncrowded. Population density, however, is just one side of the population-natural resources balance; land productivity is the other. About 80 percent of the continent cannot be considered cultivable. Half the potentially arable soils are lateritic, and thus largely unsuited for permanent field crop agriculture. Of the land that is arable, only 7 percent has naturally rich alluvial soils (Revelle 1976). Much of Africa's drier land can support only economically marginal, land-extensive uses, such as nomadic pastoralism, or at best only one meager grain crop per year. There are frequently good reasons why vast, unsettled areas have remained so. It was not by chance that they were left until last. Many regions that are unsettled today are empty precisely because they cannot support sustained settlement.

There is evidence that Africa's population is even now straining the continent's renewable natural resource base. According to a recent FAO study (Harrison 1983), almost half of Africa's land area is unable to support its current population, using current technology. By the year 2000, the study concludes, 30 countries out of 51 in the region will be unable to feed their populations with current levels of inputs. Increased technological inputs, such as irrigation, can improve yields, but at great financial expense and with high environmental costs and public health risks (Tillman 1981). As real energy costs rise, so do the costs of irrigated agriculture, which depends on electricity or liquid fuel for pumping, and often also upon such energy-intensive inputs as fertilizers and biocides. 2/ Excessive irrigation in dry climates often leads to salinization or alkalinization of crop land, such that much of the available water must eventually be used to flush away salts, rather than to irrigate crops.

Population growth rates in Africa are among the highest in the world. At current growth rates, Africa's current population of nearly 500 million will double in less than 30 years. Where high-potential lands already are crowded, the population spills over onto marginal lands, which produce low yields and are often susceptible to rapid degradation in the absence of proper management. These marginal lands are farmed ever more intensively as human numbers grow.

Yield figures suggest the stress on Africa's natural resources. Between 1969-71 and 1977-79, average annual yields of maize, millet, wheat, and cotton declined for the continent as a whole. Yields of sorghum, groundnuts, and pulses were lower in 1977-79 than in 1961-63 (World Bank 1981). Declining yields per hectare often indicate either that more marginal land is coming into production or that the fertility of the land is declining through overuse. Such land degradation severely reduces future carrying capacity.

2/ Biocides, literally chemical "killers of life," is the generic category which includes, herbicides, insecticides, fungicides, and so forth.

Declining food production per capita is another indication that population growth is outrunning the land's resources. For the continent as a whole, food production per capita declined 9 percent between 1969-71 and 1977-79. In 1980, 26 nations in sub-Saharan Africa relied on food imports for meeting the basic needs of their populations. Food imports per capita rose 15 percent in the region between 1974 and 1979 (World Bank 1981).

Food Supply

Chronic hunger and starvation do not arise purely by chance. They are caused by population growth outstripping agricultural production, by severe poverty, and by economic and environmental mismanagement.

Nearly 60 percent of the people of the developing world live in regions that have insufficient agricultural resources to support their current population densities, even if all their cultivable lands were put into production, using current technologies. That surprising statistic is the result of the most complete study of population and carrying capacity to date, to be released soon by the United Nations Food and Agriculture Organization (FAO). According to a preliminary report on this study, the developing world as a whole has the potential to support nearly twice its existing population, even with the relatively inefficient agricultural techniques currently in use (Harrison 1983). However, both agricultural resources and human populations are distributed very unevenly among countries and regions, leaving many countries' food security in a precarious position.

The ratio of population to food production has become increasingly less favorable in recent years. FAO's World Food Surveys indicate that in many regions population growth has slowed, but the growth in food production has slowed still further. Global per capita food production was once growing, but is now declining (FAO 1977a).

Egypt is a telltale example of the growing imbalance between growth in population and food production. For example, while Egypt's population growth rate between 1960 and 1976 dropped from 2.5 to 2.4 percent a year, its agricultural production growth rate fell from 3.3 to 1.4 percent a year. Despite the Aswan High Dam, the total area of irrigated farmland in Egypt has not changed dramatically over the past two decades. While additional areas are being brought under irrigation, existing arable lands are being lost to urbanization. Moreover, salinization, alkalinization, and waterlogging are impairing agricultural productivity on much of the existing irrigated cropland.

Kenya's experience illustrates how one country's food security prospects can rapidly shift from optimistic to grim. Kenya's population growth rate remained roughly constant, at 3.3 percent a year, over the period 1960-1976. During the 1960's, cereal grain production grew even faster, at 5.5 percent a year. But between 1970 and 1976, growth in agricultural production stopped (FAO 1977a). Cereal production per capita, once growing at 2.1 percent a year, was shrinking at 4 percent a year by the end of the period. Under exponential population growth, with short doubling times, change comes quickly indeed.

The distribution of income and nutrition can reveal hunger that is hidden in statistics describing average living standards. Ghana, according to the 1977 FAO World Food Survey, grew enough food in 1972-1974 to meet its people's food energy requirements of 2300 kcal per person per day. During the same period, however, one out of every five Ghanaians was undernourished, with a calorie intake of less than 1500 kcal per person per day (FAO 1977b). High population growth rates tend to widen income disparities and reduce the living standards of the "poorest of the poor" further still.

Of course, population growth is not the only cause of hunger in the Third World. In some countries, it is not even the primary factor. Economic mismanagement, such as pricing policies that provide inadequate producer incentives, can stifle agricultural productivity in countries well endowed with natural resources. Environmental mismanagement, such as land use and land tenure policies that encourage the farming of marginal lands, can cause permanent damage to the agricultural potential of a region.

Some regions have sufficient natural resource endowments to support significantly larger populations in the future. However, in many cases it may be impossible to develop these resources quickly enough to support high rates of population growth. When populations grow rapidly, resources must be diverted from development to basic sustenance. The acceleration of the Mahaweli Ganga regional development program in Sri Lanka illustrates how this problem arises.

The Accelerated Mahaweli Regional Development Program

The Mahaweli program was originally conceived as an ambitious plan to relocate one out of ten of Sri Lanka's people in previously undeveloped lands, triple electrical generating capacity, cut unemployment, and guarantee food self-sufficiency. Begun in the 1970's as a 30-year program, the Mahaweli scheme became more ambitious still when it was "accelerated" to a six-year plan in 1977. Like any large project, the Mahaweli program has had its problems. Some of these problems, however, have arisen mainly from accelerating the program, in response to the social, economic, and political pressures resulting from rapid population growth.

The frantic pace of the accelerated development scheme made successful planning very difficult. In the rush to begin the program, for example, too little thought was devoted to planning a road network. Had the development plan been pursued more slowly, there would have been time to correct the problem when it became obvious. The short timetable of the Mahaweli plan also made it difficult to arrange financial assistance quickly enough.

Perhaps the most ominous consequence of the speeding up of the timetable, however, has been the resulting emphasis on activities that generate output in the short term rather than on those that protect important natural resources for the long term. For example, the hillsides above the Mahaweli River are severely deforested. Replanting efforts have been too little, too late, because most of the program's resources have been devoted to making the dams and the croplands productive as soon as possible. Ironically, the productivity of these same dams and croplands is now threatened by sedimentation, as the denuded hillsides are eroded by rains.

Similarly, the trees that will be needed near the settlements to provide fuelwood have not yet been planted. For the moment, fuelwood is plentiful because the forest is being cleared for cropland. But when land clearing stops, the immediate supply of fuel will stop as well. Without woodlots, either severe fuel shortages or deforestation and watershed damage will result.

The final irony of the accelerated Mahaweli program is that even this crash program is not enough. Even if the full program were completed in the intended six years, it would not keep pace with Sri Lanka's population growth during this time.

Deforestation

Population pressures in much of the Third World are leading to deforestation on a massive scale. Deforestation, in turn, is causing acute human suffering, reduction in carrying capacities, and long-term damage to the prospects for sustainable development in many areas.

Demand for firewood is a leading cause of deforestation, particularly in the more arid and high-altitude regions where wood grows relatively slowly. In many areas, the population has grown beyond the carrying capacity of the local wood supply. In order to meed their daily energy needs, 1.3 billion people must cut firewood faster than it can be replaced by natural regrowth (Poore 1983). As the forests are depleted by overcutting, the carrying capacity falls still further. As sustainable production falls, people must cut further into the tree stock itself to meet their needs. If uncorrected through some type of intervention, this process continues until no economically assessible tree stock remains.

Unfortunately, it is often difficult for those who are depleting the "natural capital" of the forest to recognize that they are doing so (or to have the means available to do otherwise). Obtaining adequate wood supplies is typically seen simply as a problem of cutting enough wood, not as one of protecting the resource base that supplies wood. Usually the depletion of the tree stock is apparent only because obtaining adequate supplies has become difficult.

Managed village woodlots or more efficient wood stoves could greatly expand the energy component of the carrying capacity of these regions. However, successful introduction of fuelwood planatations, energy-efficient stoves, and other forest-conserving measures is often not easy. Such measures require local testing and adaptation, large numbers of trained personnel, and adequate econommic and institutional incentives to succeed. For example, people will not plant trees on public lands if they fear that other persons will cut them down. Even in areas of low population density (for example, much of sub-Saharan Africa), rapid population growth impedes forest conservation efforts. The large outlays of private and public capital needed for successful reforestation are diverted instead into supporting the rapidly growing population. Skilled administrative talent, one of the scarcest resources in most developing countries, is used for managing societal adjustments to high population growth, rather than for preserving economic and social sustainability through reforestation or the other activities needed to keep the natural carrying capacity from declining.

What does firewood scarcity imply for the quality of life of Third World families? In China, more than 70 million (out of 170 million) rural households--about 350 million people--suffer serious fuel shortages for up to six months each year when crop residues are exhausted and wood is unavailable in deforested areas (Smil 1983). In much of West Africa, two meals were traditionally cooked each day. Now many families can eat cooked meals only once each day or once every other day, because wood is so scarce (FAO 1978, Hoskins 1979). In Senegal, according to one peasant, "one can starve with a full granary if one has no fuel with which to cook the meal" (Hoskins 1979). Soybeans have been introduced in Upper Volta. They are exceptionally nutritious and have grown well, but they have not been used widely because they require long cooking times (Hoskins 1979). Similar experiences have been reported in Haiti (FAO 1979). To the extent that there is insufficient fuel to heat foods and boil water, diseases spread more rapidly. As the forest perimeter is cut back, families unable to afford kerosene must devote increasing amounts of labor or income to obtaining firewood. These resources are necessarily diverted from improving the household's living standards.

Another major cause of deforestation is the expansion of agriculture. According to FAO, over 11 million hectares of forest are being cleared annually by the extension of agriculture onto marginal lands (Poore 1983), primarily in response to population pressures. These marginal lands are usually unable to support permanent agriculture, at least in the absence of very high levels of commercial inputs. When ecologically fragile marginal lands are cultivated, they tend to become quickly eroded and infertile. When this happens, the settlers move on to clear more forest, thus repeating what is often a destructive and unsustainable process.

Soil degradation due to deforestation is most acute in tropical moist forests. Despite their lush plant growth, most tropical rainforests grow on infertile, highly acidic soils. In these ecosystems, most nutrients essential to plant growth are stored in the vegetation, not in the soil. Thus, when the forest is cleared, minerals essential to crop growth either volatilize or wash deep into the soil, beyond the reach of non-tree crops. This soon breaks the nutrient cycle, making it difficult to sustain more than two or three harvests of annual crops. The application of fertilizers as a remedial measure is usually uneconomical, because of the high cost of fertilizers and because soil conditions in many tropical areas limit their effectiveness. Moreover, with forest cover removed, the exposed ground often becomes heavily eroded; sometimes, it bakes under the tropical sun into a hard, uncultivable surface. These ecological realities were primarily responsible for the relative lack of success of Brazil's Transamazonica Highway project, designed to settle large numbers of small farmers in the Amazon region. After four years, the project was judged by Brazilian officials to be less than 7 percent successful, primarily because of unsuitable soils (NAS 1980).

In addition to the fuelwood and other important products they supply, forests provide a wide range of "environmental services" that support economic development in such sectors as agriculture, energy, and transportation. These environmental services, such as protection of soil and maintenance of water flow patterns, are frequently overlooked or underestimated because they are "public goods," not priced in the marketplace. Nonetheless, the loss of these environmental services through inappropriate deforestation often causes costly development failures and much human suffering. Human population growth is one of the principal forces (though by no means the only one) behind rapid deforestation in much of the developing world (Ledec 1983, NAS 1980).

Forests support the agricultural sector in a number of important ways. By retaining water and releasing it gradually throughout the year, forests prevent or minimize excessive flooding during rainy periods. This helps prevent the erosion of productive soils in downstream agricultural areas (World Bank 1978). Forests also protect soils on agriculturally marginal lands, until economically viable and ecologically sustainable cropping or silvicultural techniques can be introduced. Conserving natural forests is often far less costly than rehabilitating marginal lands degraded by inappropriate clearing or subsequent misuse.

Even more importantly, forests and other well-vegetated natural areas help maintain the productivity of irrigated agriculture. By releasing water gradually on a year-round basis, they help ensure an adequate water flow to support irrigation during the dry season and prevent inundation of crops during the wet season. Furthermore, by stabilizing soils, they greatly reduce sedimentation of irrigation canals, thereby preventing the need for costly inputs of labor and capital to keep these systems functional. All told, some 40 percent of developing world farmers live in villages that depend upon the watershed functions provided by forests. Agricultural export crop production, valued at $36 billion a year, depends upon the water supply and soil stabilization functions of forests (Clay 1982).

When forests or other well-vegetated wildlands are eliminated, the damage to agricultural output can be severe. For example, the capacity of India's Nizamsagar Reservoir has been reduced from almost 900 million m^3 to less than 340 million m^3 by sedimentation resulting from deforestation. As a result, there is now not enough water to irrigate the 1,100 km^2 of rice and sugar cane for which the reservoir was intended, and local sugar factories have considerable underutilized capacity (IUCN 1980).

Aside from their provision of fuelwood, forests are important to the energy sector of developing countries for protecting and enhancing the power production of hydroelectric dams. When forests or other well-vegetated watersheds are cleared, reservoirs often become much shallower due to sedimentation. As a result, less electricity can be generated (because less water can flow through the turbines) and the useful economic life of the hydroelectric investment is shortened. For example, the useful life of the Ambuklao Dam in the Philippines has been cut from 60 to 32 years because of deforestation (USAID 1979). Deforestation has also led to daily electricity rationing in Bogota, Colombia, by causing the Guatavita hydroelectric complex to operate at only one-sixth of normal capacity (World Environment Report 1981). In recent years, China has built dams to add about 260 million cubic meters of new water storage capacity per year; however, about 80 million cubic meters (30 percent) are being lost each year due to sedimentation (Smil 1983). Such losses in power generation capacity translate into impaired industrial growth or the massive expenditures required for reservoir flushing or dredging (even if practicable) or construction of replacement facilities for generating power.

Forest cover is often also important in maintaining the efficiency of the transportation sector. For example, the flood control and soil stabilization functions of forest help protect roads in mountains and high rainfall areas from being made impassable by floods and landslides, both serious problems in steep deforested areas such as Nepal and parts of Colombia. By preventing soil erosion and the resulting sedimentation, forests and other natural areas similarly help keep harbors and navigation canals functional. Deforestation is jeopardizing the continued operation of Panama's most important economic asset, the Panama Canal, which suffers from heavy sedimentation and a lack of sufficient water during the dry season to operate the locks for the larger ships (USDS 1978). Similarly, it costs Argentina $10 million a year to dredge silt from the Plata River mouth and keep Buenos Aires open to shipping; 80 percent of sediment load comes from only 4 percent of the drainage basin--the small but heavily overgrazed watershed of the Bermejo River, 1,800 kilometers upstream (Pereira 1973). In Thailand, important waterways are no longer navigable because of sedimentation resulting mainly from deforestation (Clay 1982). The careless cutting of forests (or other forms of environmental mismanagement) can thus entail serious economic losses in maintenance expenditures, foregone revenues, and generally reduced economic activity.

Deforestation also increases the human and economic losses from natural disasters. Storms, floods, and droughts become major catastrophes when vegetation buffers are removed. For example, typhoon damage in the Philippines amounts to roughly $20 million per year, through floods and landslides that are greatly intensified by deforestation of upland watersheds and removal of mangrove or other coastal swamps which can buffer coastal flooding (UNEP 1980). In China, severe deforestation and erosion in Sichuan and Yunnan provinces have been identified as important causes of record floods along the middle course of the Yangzi River in 1982 and 1983. India and

Bangladesh suffer billions of dollars of property damage and tragic losses of life in annual floods of the Ganges River, made more serious by deforestation in northern India and Nepal.

Reclaiming the Himalayan Watersheds

The Ganges River, which flows through India and Bangladesh, floods annually, causing millions of dollars of damage and incalculable human suffering. These annual floods are made much more severe by two types of population pressure. In the lowland areas surrounding the Ganges, population growth and competition for land has forced many people to live too close to the river, in the path of the annual floods. In the mountainous watersheds of northern India and Nepal, population growth has led to severe deforestation, causing the area's heavy rains to run off rather than soak into the soil. As testimony to the effects of population growth, the severity of flooding has increased exponentially over the past 20 years, even though the annual rainfall has remained essentially the same.

To help combat the problem, the World Bank is funding a pilot project in Uttar Pradesh State, India, to develop nine small watersheds covering 312,000 hectares. The project will attempt to reclaim denuded hillsides by establishing extensive tree plantations. To help alleviate the erosion caused by free-running livestock, stall feeding of livestock will be encouraged. Terracing of agricultural lands will further slow runoff and erosion.

Desertification

Closely related to the environmental problem of deforestation in the more arid climates is desertification. Desertification is a human-caused process by which the inherent productivity of semi-arid land is lost, often irreversibly, through mismanagement. The effects of desertification are often confused with those of drought. Drought results from natural fluctuation in weather patterns; desertification results from human mismanagement of lands that are often prone to droughts. In both cases, the economic productivity of the land is reduced, sometimes to zero. However, droughts, no matter how severe, are ephemeral occurrences; when the rains return, the land's inherent productivity is fully restored. If desertification occurs, however, a return to normal rainfall can never fully restore the land's productivity. If the desertification is severe, the land may remain unproductive for many human generations, unless costly remedial measures are taken. While drought can trigger rapid desertification and can make its effects more keenly felt by those living in the affected area, most scientists agree that changes in climate are not responsible for the vast areas of semi-arid land going out of production each year (Grainger 1982).

The economic and human losses related to desertification can be staggering. Although some 100 countries are affected by desertification, the process is most serious in sub-Saharan Africa (particularly the Sahel), southwestern Asia, and the Middle East. Every year, some 200,000 km^2 (an area larger than Senegal) are reduced by desertification to the point of zero economic yield (Grainger 1982). The lost agricultural production is about $26 billion a year--roughly equivalent to the Gross Domestic Product of Thailand (Grainger 1982). The human costs of desertification often include malnutrition, the threat of famine, and the dislocation involved when peasants or pastoralists must abandon their lands to seek employment elsewhere (for example, in urban slums). The United Nations Environment Program (UNEP) Executive Director, Dr. Mostafa Tolba, wrote in 1982 that, despite all efforts to control it, there is no doubt that the process of desertification actually is accelerating. More than 20 percent of the earth's surface--presently the home of 80 million people--is directly threatened by desertification (Grainger 1982).

The proximal causes of desertification include overcultivation, overgrazing, and deforestation. All of these activities strip vegetation from the topsoil and deplete its supply of nutrients and organic matter, thereby leaving it exposed to the eroding forces of the sun and wind. The topsoil can become as dry as dust, and blow away in the wind. The remaining subsoil can become hard and impervious. It then can no longer absorb the rains when they come, and the water flows away over the surface, carrying away soil and cutting gullies which become deeper and wider year by year. In all of these situations, people are taking more from the soil than they should. They are not replacing soil nutrients, not allowing the land enough time to recover under fallow, or not restoring vegetative cover so that it can protect the soil from erosion. In this manner, they are consuming the land's natural capital, rather than sustainably living off the interest.

To a large extent, the proximal causes of desertification are "driven" by the pressures of rapid population growth. As rapidly expanding farmer or pastoralist populations require more food for themselves and their livestock, they frequently exceed the limited carrying capacity of semi-arid areas. When they attempt to keep production levels high during times of drought, they reduce the land's natural resilience and initiate a process of permanent degradation. Even in those situations where the existing population size is not pressing against the land's carrying capacity limits (even during dry years), a high rate of population growth makes it exceedingly difficult to control desertification. The methods needed to control desertification include grazing controls, tree planting, and improved agricultural techniques. To be effectively implemented, such activities require administrative talent and large numbers of trained personnel. Such resources, always at a premium in the developing world, become especially scarce when they are diverted to address the numerous economic, institutional, and social adjustments that become necessary as a result of high population growth. Rapid population growth brings about the need for governments to feed or employ thousands or millions more people each year; in the face of such pressures, longer term problems such as desertification receive insufficient attention.

Loss of Biological Diversity

One of the irreversible consequences of today's rapid population growth is the loss of biological diversity, at a rate and scale that may be unprecedented in the history of life on earth. The best available estimates suggest that, if current trends continue, some 15-20 percent of the estimated 3.5-10 million species of plants and animals alive today may become extinct by the year 2000 (CEQ 1980, Myers 1979, and Ehrlich and Ehrlich 1981). The most important cause of the extinction of today's species is the disappearance of the natural ecosystems upon which the species depend. Because they are naturally so rich in species, the loss of tropical forests is particularly important in reducing the earth's stock of species. As indicated above, population growth is only one of the causes of tropical deforestation (or the loss of other ecosystem types); however, it is one of the most important.

Why is biological diversity important? There are compelling ethical, aesthetic, and economic reasons for humanity to take all reasonable measures to avoid causing the extinction of other species. The ethical justification is that a growing number of people believe that human beings do not have the right to obliterate other species of living things at will--even those species not known to have any practical value to humankind. Although this ethical value is not universally shared, extinction is a completely irreversible process, and to extinguish other species is to deny the options available to all future generations of human beings. For essentially one or two generations of humans to eliminate unnecessarily a sizeable proportion of the diversity of life on earth is, at the very least, an act of considerable arrogance. Therefore, while human society is confronted with numerous pressing short-term problems, any action with such profound and everlasting consequences as causing an extinction should also be weighed carefully.

The aesthetic justification is that many wild species of plants and animals are an irreplaceable source of wonder, inspiration, and joy to humans. This aesthetic value has only partially been translated into economic value, through such activities as bird feeding and wildlife photography. However, millions of people derive enrichment merely from knowledge of the existence of many wild species they never see; this "vicarious satisfaction" has no market value.

The main economic justification for species preservation is that numerous wild plant and animal species are "undeveloped resources," in that they have major economic potential that is currently undiscovered or underutilized. The preservation of biological diversity is important to the maintenance and improvement of agriculture, forestry, ranching, fisheries, medicine, and industry. For example, a recently discovered species of wild perennial corn (_Zea diploperennis_) may become of considerable importance in promoting increased food production, even though it seemed at first to be "just another weed" growing on a hillside in Jalisco, Mexico. Human society is indeed likely to be better off because this apparent weed was not eliminated by conversion of all of its natural habitat to agriculture or other uses (USDS 1982).

Similarly, over 40 percent of all prescriptions written in the United States contain one or more drugs originating from wild species (Farnsworth 1982). In some cases, it is impossible or more costly to synthesize these compounds than to obtain them from living sources; in other cases, it would not have been possible to know what compound to synthesize without first having the natural model.

Wild plant and animal species are also of great importance to industry, providing tannins, resins, gums, oils, dyes, and other commercially useful compounds. Even the rubber tree (Hevea basiliensis) was once just another Amazon tree species of unknown value. There is tremendous, although impossible to quantify, potential for new industrial products from currently unknown or poorly-known plant and animal species. These may even include hydrocarbons for an oil-short world: it was recently discovered, for example, that Copaifera landsdorfii, a tree that grows in northern Brazil, manufactures sap that can be used directly in diesel engines (IUCN 1980a).

These few examples illustrate the range of economic uses of many wild plants and animals. It is important to note that 80 percent or more of all the world's species of plants and animals have never even been catalogued and given a scientific name, much less studied thoroughly for possible human uses (NAS 1980b). Biological resources, unlike petroleum and other fossil fuels, are completely renewable, but only if care is taken not to destroy them before their value can be realized. Eliminating much of the world's vast wealth of biological diversity, because of lack of attention or short-term expediency, has been likened to "burning the world's libraries for one winter's warmth."

Pollution and Public Health

Although more localized and reversible than problems of natural resource degradation, pollution in developing countries can also have debilitating effects on economic development and human well-being. One of the most important forms of pollution in developing countries is biocide abuse. While they are of considerable value (especially when used judiciously in a system of "integrated pest management"), biocides can do far more harm than good when applied excessively or without proper precautions. They destroy the natural predators of insect pests and the pollinators of crops, promote the rapid evolution of biocide-resistant insect varieties (whether crop pests or disease vectors), kill fish, and poison some 500,000 peasants each year (NRDC 1980). A variety of industrial chemicals also kill crops and fish and damage human health in developing countries. While limited in area, urban air and water pollution in some developing country cities (such as Bangkok and Mexico City) may be so extreme as to limit economic development by choking off certain growth possibilities, forcing expensive and unwieldy industrial decentralization plans for outlying areas, and damaging the health of the urban labor force (Leonard 1983). Another, more widespread health problem in developing countries is the mounting incidence of water-borne diseases that accompanies the construction of large dams and irrigation projects. Poor sanitation and the frequent lack of safe drinking water continue to be serious public health problems, as witnessed by the millions of children who die annually from diarrheal and other sanitation-related diseases.

These and other types of pollution can all be readily controlled, if adequte investments are made in the appropriate machinery or techniques. However, it is difficult to summon the necessary financial capital and scientific and administrative talent when these scarce resources are already stretched to their limits in managing the necessary societal adjustments to rapid population growth. Furthermore, very high urban population densities, which are in part the result of rapid nation-wide population growth, tend to concentrate pollutants, thereby making effective control more difficult and expensive.

Population Growth and the "Low-Potential Region" Phenomenon

It is not difficult to understand that the most attractive regions for human habitation tend to be the ones that are presently the most densely settled. High carrying capacity (or "high potential") regions tend to have fertile soils, adequate fresh water, easy access to transportation links, and abundant natural resources; they yield relatively high returns on investments made. Consequently, they attract large numbers of people and substantial investment capital. Rapid population growth, however, induces many people to move from high carrying capacity regions to those of lower carrying capacity. This can occur because employment creation does not grow as rapidly as the population, or because the existing high population density compels people to overexploit the region's natural resources, thereby exceeding (and further reducing) its carrying capacity.

Low carrying capacity (or "low potential") regions, on the other hand, are relatively poor in accessible natural resources; they may be too dry, lacking in good soils, disease-ridden, or unduly remote (thereby inhibiting trade). Investments in low potential regions yield relatively low returns; in many cases, the benefits of such investments do not exceed the economic costs. Because the costs of bringing low capacity, or "marginal," lands into production can be very high, it is economically preferable to invest in measures to reduce population growth, thereby minimizing the need to make expensive investments in expanding the carrying capacity of marginal lands. The experiences of Indonesia's Transmigration Program illustrate this point.

Indonesia's Transmigration Program

Indonesia, the world's fifth most populous nation, is characterized by a very uneven distribution of its population. Of the country's roughly 150 million people, some 65 percent live on Java and the smaller islands of Bali and Madura, which together comprise only 7 percent of Indonesia's land surface. In contrast, large areas of the "Outer Islands," including Sumatra, Kalimantan (part of Borneo), Sulawesi, and Irian Jaya (part of New Guinea), are very sparsely populated. This apparent imbalance is in large measure explained by environmental factors. Java, with hundreds of volcanoes, is blessed with exceptionally fertile volcanic soils, which permit extremely intensive agriculture and sustain a rural island-wide population density of over 600/km^2 (up to 2,000/km^2 in some rural districts). On the other hand, large areas of the Outer Islands are characterized by highly infertile, acidic, thin soils that are poorly suited for intensive agriculture. As people have migrated among Indonesia's islands for centuries, it is understandable that so many have settled on Java.

Java's rapid population increase is testing the island's agricultural carrying capacity. If current trends continue, Java will have less than 0.1 hectare of land per capita by the year 2000 (Goodland 1981). Population pressure on Java is encouraging ecologically unsound agricultural practices (for example, cultivation of very steep slopes), which have already degraded over 23 million hectares of what the Government calls Tanah Kritis ("Critical Lands") (Goodland 1981). Moreover, a sizable proportion of Java's labor force is unemployed or underemployed, as employment creation has failed to keep pace with population growth.

For these reasons, migration to the Outer Islands can seem attractive as a "safety valve" for Java's population growth. The Indonesian Government is conducting its transmigration program in order to move large numbers of people from Java and Bali to the Outer Islands. Since 1978, the transmigration program has entailed expenditures of roughly $2 billion, of which approximately $350 million was loaned by the World Bank.

Like many other large-scale, government-assisted land settlement schemes, the transmigration program has achieved mixed results. Agricultural yields on many sites have been disappointingly low, while the economic costs of clearing and preparing the land and providing the necessary infrastructure have been high. Significant environmental costs have also occurred, including deforestation, soil degradation, and the increased incidence of malaria and other public health problems. In part because of the emphasis on settling large numbers of families quickly, the program's costs have been high--roughly $5,000 per family settled.

Despite the large financial investment and the high priority given by the Government to transmigration, the program has never succeeded in moving even 100,000 people per year, while Java's annual population increase is more than 2 million (Goodland 1981). Clearly, transmigration is not a viable option for solving Java's population problem. A more important justification for the transmigration program than relieving population pressure on Java has been to promote the economic development of the Outer Islands by increasing their labor supply. However, given the difficult nature of the soils and other development constraints of the transmigration sites, the most efficient development of the areas can be obtained only through adequate advance planning and site selection. To the extent that it has provided an impetus for accelerating the program, the population pressure on Java has made such careful planning more difficult. As a result, many natural and financial resources have been wasted.

In 1966 the Government reversed Indonesia's pronatalist policies. In 1969 it launched a vigorous national family planning program. Since then, population growth on Java has fallen from 2.1 to 1.5 percent. Indonesia's family planning program has been distinguished by strong Government support and a highly acclaimed local approach that goes far beyond the more traditional clinic system. The direct involvement of local village leaders as motivators, field workers, and even contraceptive distributors has been central to the program's success to date. The annual cost of Indonesia's family planning program from 1979 to 1983 has been roughly $53 million. This compares favorably with the annual costs of transmigration (approximately $400 million)--and the results, in terms of reducing population pressure on Java and Bali, have been far more impressive.

Indonesia is not the only country where investments in expanding the carrying capacity of low-potential regions are not likely to be as effective as family planning in reducing population pressures in high-potential regions. Other examples of economically and environmentally costly land settlement schemes, stimulated at least in part by population pressures in high-potential areas, include the Northwest Region and Transamazonica Highway projects in Brazil, several in the Amazon regions of Peru and Colombia, Sri Lanka's Mahaweli Ganga program (mentioned above), Nepal's Terai settlement, and Kenya's Bura Irrigation Settlement project.

Converging Demands on Scarce Natural Resources

A growing problem in many developing nations is the competition for different products from limited land resources. Often land, whether cropland or forest land, is in short supply. Where this is the case, allocating those scarce lands among competing uses becomes a major concern.

Production of food crops faces increasing competition with energy crops for valuable land space. Energy cropping has great potential for providing fuelwood and, in some cases, liquid fuels to fuel-poor Third World nations. However, energy cropping in land-poor countries often requires diverting land from food to non-food crops.

Establishment of fuelwood plantations requires first and foremost an investment of land sufficient for growing trees. Often such land would otherwise be used for food production. However, competition for land can be reduced if wood production can be accomplished on otherwise unused land. In South Korea, fuelwood is grown on mountain slopes of little agricultural value. The tree plantations also serve to reduce flooding and soil erosion on the steep slopes.

Social problems inherent in large-scale production of energy crops may surface first in Brazil, where such schemes are well advanced. Despite the possibility that energy crops could be produced in addition to, and not instead of, food crops, the volume of fuel required for Brazilian automobiles indicates that energy cropping might require up to one-fifth of Brazil's existing cropland, in addition to agricultural investment capital, water, fertilizer, and other inputs. Brazil may well become self sufficient in fuels, but in the process become more dependent than ever on food imports. Brazil is already the largest grain importer in the Western Hemisphere.

Diversion of cropland to energy crops is likely to drive food prices up, thereby further pricing the urban poor out of the market.

Indeed, even crop and animal wastes are the object of conflicting demands. Traditionally, agricultural wastes are used for fertilizer. In heavily deforested areas, however, people may turn to burning crop wastes or animal dung instead of all-too-scarce firewood. Diversion of this resource from fertilizer to fuel use results in a loss of agricultural productivity. A generally accepted estimate holds that each metric ton of cattle dung that is burned rather than used as fertilizer means a loss of around 50 kilograms of potential grain output. Since some 400 million metric tons of dung are burned annually in Asia, the Near East, and Africa, annual losses in potential food output total 20 million metric tons, or very roughly 15 kilograms of grain for each person in these regions.

According to a World Bank analysis, in Nepal alone the amount of dung that may be burned in the year 2000 will reduce grain production by about one million tons, or one quarter of Nepal's total annual grain production. Radical boosts in tree planting are needed to offset the deforestation which forces rural people to burn dung.

The food producing capacity of a region is lowered if land suitable for growing food is used instead for the production of firewood or other energy crops. However, both energy and food production are vital to development efforts. People must be able to cook most of the food they grow. Conversely, all the firewood in the world cannot help those who have no food to cook. Balancing conflicting demands for scarce, finite resources is a continuing challenge for sustainable development. Expanded efforts to control population growth can minimize such difficult trade-offs as these.

Summary and Conclusions

When human populations are kept in balance with the natural resources that support them, sustainable development is possible. When human populations grow too quickly, or become too large, they damage their essential natural resource base, thereby making sustainable development impossible. In many regions, environmental stresses now indicate that the human population may be too large or growing too quickly.

Natural resources, whether renewable or nonrenewable, are inescapably finite. Thus, for developed and developing countries alike, the question is not whether there are ultimate limits to population growth. The question is which of these limits a region will encounter first, and when. If population growth is not limited by conscious human control, it is likely to be limited by factors related to natural resource constraints.

Populations cannot be sustained beyond the carrying capacities of their regions. To develop sustainably, countries have only two viable choices. First, they can act to lower their population growth rates, through measures such as family planning. Second, they can seek to expand sustainably their carrying capacities. While both options are necessary for most developing countries to bring their populations into a sustainable balance with their natural resource base, the former option has often received insufficient attention, relative to the latter. Moreover, because carrying capacity cannot be increased forever, pursuing the second policy at best only delays the need to adopt the first.

There is also a third option, one which is not viable. That is to liquidate the capital of the natural resource base for one-time use, thereby temporarily supporting a population larger than the carrying capacity. In many areas of the world, this third option is being pursued because, in the short term, it is less costly and requires less social cooperation than the other two. The environmental stresses and natural resource degradation described in this paper are products of this third course of action. The third option ultimately destroys a society's chances for successful, sustainable development. To be sustainable, a society must "live within its means" in terms of natural, as well as human and financial, resources.

Because of the very long "lag" periods inherent in population planning (1-2 human generations), considerable foresight capability is needed to assess possible future carrying capacity limitations and resulting environmental stresses. The existing evidence strongly suggests that many developing countries are already suffering severe problems related to environmental and natural resource degradation. Even those countries that still have favorable population-natural resource balances would be well advised to undertake vigorous population policies, because such favorable balances can easily become unfavorable within the long period required for the full effect of population policies to be felt. Aside from the question of stabilizing population size because of on carrying capacity limitations, the negative environmental consequences merely associated with a high rate of population growth provide a compelling case for urgent efforts to reduce such growth.

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To village people, politicians, and international health planners, health and family planning have always seemed to fit naturally together. But in the early 1960s, when international awareness of the social and economic consequences of surging population growth moved family planning into a position of high priority, some international agencies began to advocate separation of family planning from health services. In international policy discussions the question continues to be important. This volume analyzes this question and provides arguments and evidence to support integration of health care and family planning; it outlines the purposes underlying the research in this area; and it proposes policy questions regarding the effectiveness, efficiency, and equity of such an integration.

The Johns Hopkins University Press. 1984. 256 pages.

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K. C. Zachariah and others

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A joint World Bank-OECD study. Oxford University Press, 1981. 166 pages (including 22 maps, bibliography, index).

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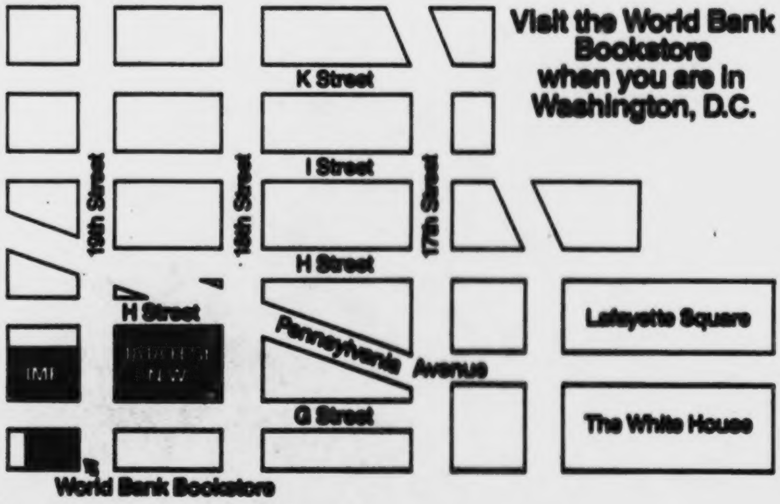

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